# ECOLOGICAL CHARACTERISATION AND EFFECTS OF FIRE AND GRAZING ON *Cyrtanthus nutans* (R.A.Dyer) IN NORTH-WESTERN KWAZULU-NATAL, SOUTH AFRICA

by

**LYNNE MICHELLE RUDDLE**

Submitted in accordance with the requirements for
the degree of

**MASTER OF SCIENCE**

In the subject

**Environmental Science**

at the

University of South Africa

**Supervisor: Dr Erika van Zyl**

**MAY 2018**

*"Conservation is getting nowhere because it is incompatible with our Abrahamic concept of land. We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect."*

**Aldo Leopold**

# ABSTRACT

*Cyrtanthus nutans* (RA Dyer) is a KwaZulu-Natal Province near-endemic species, classified as vulnerable in South Africa (IUCN Red Data categories). Literature references suggest that no recent ecological research has been conducted on *Cyrtanthus nutans*. Last assessed in 2007, the current study determined the demographics and the abiotic and biotic factors that influenced the distribution and range of *Cyrtanthus nutans*.

Key determinants influencing the autecology, distribution and population dynamics of *Cyrtanthus nutans* were investigated. Anthropological factors influencing the decline of populations were addressed. Two investigations were undertaken for the current study on *Cyrtanthus nutans* in Dundee in North-western KwaZulu-Natal, South Africa namely a survey to determine the population dynamics and autecology of the species and the effect key determinants have on the recruitment and survival. Sites of occurrence and the ecological and anthropological factors that influence the existence of plants were documented. Experimental plots were conducted to determine the influence of climatological factors, fire and defoliation on the emergence and survival of *Cyrtanthus nutans* plants.

A preference was found for soils with high nitrogen and organic carbon, low phosphorus and acidity levels situated on slopes of < 10% on mid to lower terrain slopes within an altitude range of between 1 100 and 1 300 m (a.m.s.l.) in the Sour Sandveld and Moist Tall Grassveld Bioresource Groups.

The influence that climatological factors, fire and defoliation had on the emergence and seed recruitment of *Cyrtanthus nutans* were determined through a small plot experiment in the Dundee area. Mean relative humidity (%) and mean rainfall two weeks before emergence in conjunction with treatments were highly significant ($P<0.001$). Burning treatments B (fire inclusion and defoliation inclusion) and BC (fire inclusion and defoliation exclusion) were more highly significant on the emergence of *Cyrtanthus nutans* plants than any other treatments.

Increasing fragmentation of thriving populations of *Cyrtanthus nutans* populations is occurring through landuse change, mismanagement of veld and non-compliance of legislation. Continued monitoring and awareness is essential in the survival of this species.

**Key words**

*Cyrtanthus nutans*, distribution in North-western KwaZulu-Natal, population dynamics, autecology, conservation status, seedling recruitment, fire, defoliation

# DECLARATION

**Name:** Lynne Michelle Ruddle

**Student number:** 40549925

**Degree:** Master of Science

**Ecological characterisation and effects of fire and grazing on *Cyrtanthus nutans* (R.A.Dyer) in North-western KwaZulu-Natal, South Africa**

I declare that the above dissertation/thesis is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

L.M.RUDDLE 15 MAY 2018

________________________ _____________________

SIGNATURE DATE

ACKNOWLEDGEMENTS

The support of many people contributed to the successful completion of this dissertation. My heartfelt appreciation is expressed to the following people who, in so many ways, provided invaluable support and assistance during the course of this study.

To my supervisor, Dr Erika Van Zyl, without your assistance and dedicated involvement every step throughout the process, this research would have never been accomplished.

To my husband, Peter and son, Matthew, who had tremendous patience during the research work. For the time and space they gave me to complete my work and for all their assistance during the field work.

To Douglas Gordon for his tremendous input and knowledge on the geology and soils information and his advice on the way forward.

To Dr Jorrie Jordaan, for his patience, knowledge and advice during the final stages.

To Hein Potgieter for his support and allowing access to his farm to complete the experiments and all the other landowners who gave me access to their properties.

To Marie Smith for her assistance and patience during the statistical analysis sessions.

To family and friends for their support and patience during this time, and for looking for populations of my flowers on their travels.

To those I may have inadvertently left out, a collective thank you.

# TABLE OF CONTENTS

# LIST OF FIGURES AND TABLES

# CHAPTER 1

# INTRODUCTION AND BACKGROUND

## 1.1 INTRODUCTION

The irreversible transformation of natural vegetation for development and expansion of urban infrastructure as well as agricultural practices, are the main threats to loss of biodiversity and habitat in South Africa (Hall *et al.* 1980).

The rate of land transformation in the KwaZulu-Natal Province (KZN), South Africa has reached such proportions that it is higher than any other area in Southern Africa, with more than 35% of the province being transformed. According to the South African National Biodiversity Institute, this has resulted in a quarter of South African flora being either threatened with extinction or becoming a conservation concern. Currently, 0.2% of South African floral species have become extinct, 13.4% are threatened and 11.8% are of conservation concern. KZN has the third highest number of taxa (5 260 taxa) in the country. Of those, 231 taxa are threatened and 486 are of conservation concern. Of the 5 260 taxa, 424 are endemic to the province, with 114 listed as threatened species and 207 listed as of conservation concern (SANBI, 2017).

In Southern Africa, of the 57 species of the *Cyrtanthus* genus (Family Amaryllidaceae), two species are listed as “Critically Endangered”, five as “Endangered”, eight as “Vulnerable” and three as “Near Threatened”, classified according to the IUCN Red List Categories and Criteria, an internationally recognised scientific system used in South Africa. In addition, two species that are non-IUCN categorized but are considered as conservation concerns, are listed by SANBI as “Critically Rare” (species are found at a single site but there are no direct potential threats), three species as “Rare” (meets one of four South African criteria for rarity but there are no direct potential threats), one is “Declining” in numbers (the continuing decline of the species is due to threats to habitat, ecosystem or species) and two are “Data Deficient”. According to SANBI, *Cyrtanthus nutans* is listed as one of the eight Vulnerable *Cyrtanthus* species in South Africa (SANBI, 2012).

Historically, *Cyrtanthus nutans* populations were recorded as abundant in widespread areas in the Dundee District (S28° 09.888'; E30° 14.051') and areas in an easterly direction towards Vants Drift at the Buffalo River, near Nquthu, KZN. The species was identified ten years later in the Piggs Peak region and the hills of Mbabane in Swaziland. The 2007 SANBI red list assessment described the distribution as "disjunct", occurring at only five locations in north-western KZN, South Africa and north-western Swaziland (Scott-Shaw *et al.* 2007).

A number of National and Provincial Acts are legislated for the sole purpose of environmental and agricultural land protection. Key challenges for the enforcement of legislation include the lack of resources and manpower in Government departments. This, over time, has allowed the non-compliance of critical legislation by landowners, opportunists, botanical enthusiasts and uninformed members.

Taking into account the conservation status and the current legislation to protect *Cyrtanthus nutans,* the purpose of this study was to determine if there has been a change in the distribution of this species from what was previously recorded, if environmental and topographical factors play a role in its distribution and if current management practices have the potential to increase or decrease the population size in the future.

## 1.2 BACKGROUND

The construction of a new housing development in 2006 in Dundee, north-western KZN (Figure 1.1) led to the unsuccessful relocation of *Cyrtanthus nutans* plants from the construction site to three separate, locally situated sites by staff of KZN Wildlife and Department of Environmental Affairs. The development had been approved by the Dundee Municipality in the early 1970's before any National or Provincial legislation had been passed.

The lack of knowledge regarding biodiversity, legislation and environmental management guidelines resulted in many changes in biodiversity in Municipal areas. The general lack of awareness by residents regarding *Cyrtanthus nutans* is apparent when discussions are held. Planned housing developments and road upgrades through the Municipality were terminated in areas where *Cyrtanthus nutans* occurs (J Mitchell, 2006: Personal Communication).

In 2012, informal investigations into the distribution of the species by the author (as employee as a District Conservation Officer with KZN Wildlife), led to the documentation and mapping of C*yrtanthus nutans* populations at 13 separate sites in an area of approximately 960 km$^2$ from the Dundee Central Business District (CBD) to an area 31 kilometres south east on the Noustrop Pass, Helpmekaar (Figure 1.1).

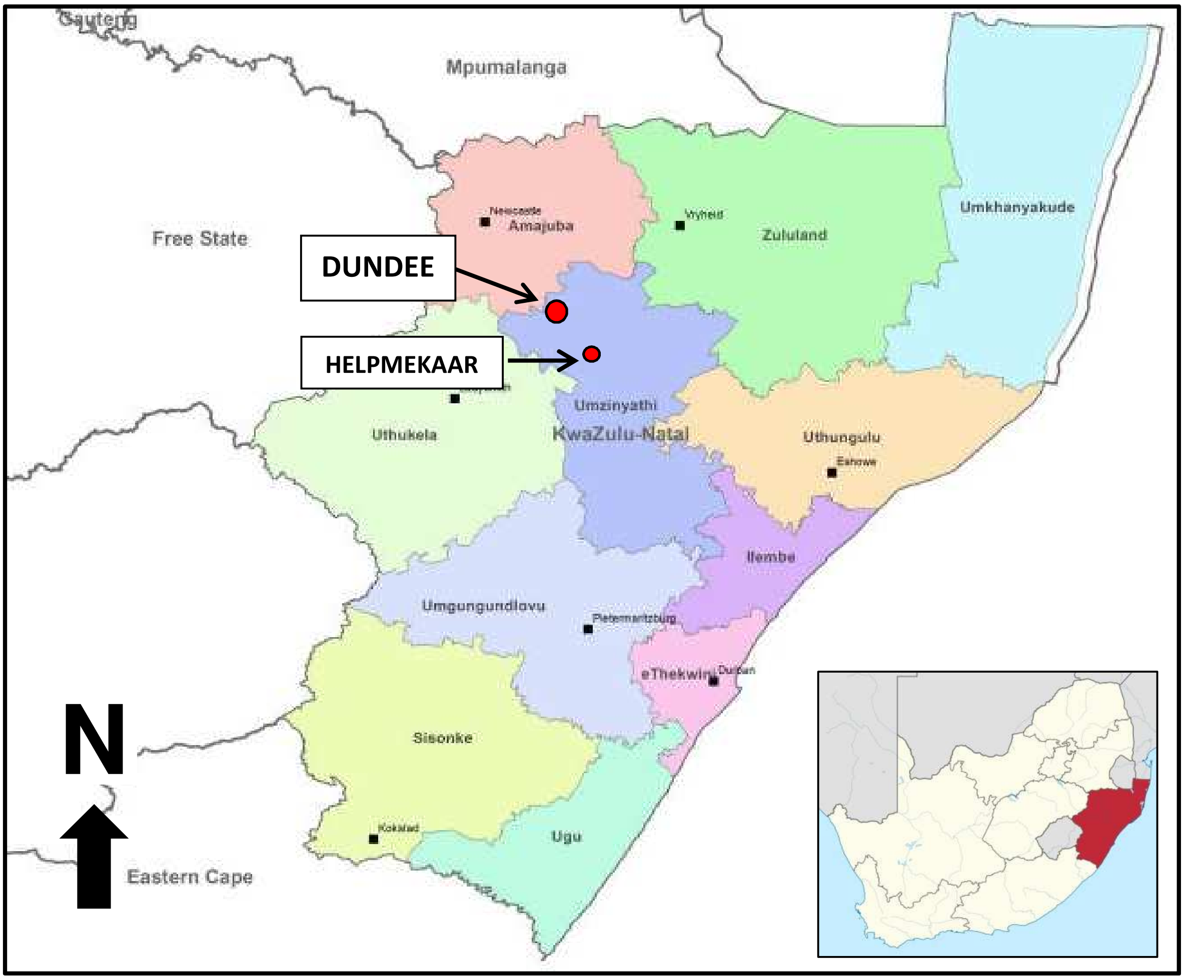


**Figure 1.1: Location of Dundee and Helpmekaar in the Umzinyathi District Municipality (UDM) in KwaZulu-Natal, South Africa.**

Each subsequent year up to and including 2016, additional sites were documented and mapped. Burning regimes of landowners and the emergence or non-emergence of plants at known sites led to the rationale behind the influence of defoliation and burning on the emergence of plants on an annual basis.

## 1.3 RATIONALE

Implementing biodiversity awareness amongst land users is the key challenge of environmentalists in South Africa. Ignorance of legislation and lack of knowledge of basic management practices is a major factor in biodiversity loss and needs to be resolved before further loss of biodiversity occurs. The implementation of correct management practices can ensure ideal conditions for optimum growth and reproduction of a species which is vital for their survival. The deficiency in critical information of a large number of South African botanical species together with increasing habitat modifications places them at risk of becoming threatened or vulnerable before essential measures can be taken to ensure no further loss of populations or vital habitat occur. Knowledge of distribution, dynamics and risks for any species, including *Cyrtanthus nutans*, are fundamental in ensuring that trends in populations are monitored.

## 1.4 RESEARCH QUESTIONS AND HYPOTHESES

The objective of this research work was to determine the effects that abiotic, biotic and anthropogenic influences have on the *Cyrtanthus nutans* population and its distribution patterns. The current study attempted to find adequate answers to each of the following questions based on the representative sample, findings and analysis;

- What is the current distribution of *Cyrtanthus nutans*?
- What is the current *Cyrtanthus nutans* population density?
- What environmental factors influence the distribution of the species?
- How does fire and defoliation influence the emergence and recruitment of seedlings?
- What factors influence the population's success or decline?

## 1.5 OBJECTIVES

Two investigations were undertaken for the current study on *Cyrtanthus nutans* in KZN, namely a survey to determine the population dynamics and autecology of the species and the effect key determinants have on the recruitment and survival. The study had the following specific aims and objectives:

1. Determining the range and distribution of *Cyrtanthus nutans*
2. Assessing the density of the population of *Cyrtanthus nutans*
3. Investigating and identify environmental and non-environmental factors that act as determinants for the presence of *Cyrtanthus nutans*
4. Examining the influence of fire and defoliation on the emergence and recruitment of *Cyrtanthus nutans* within experimental sites
5. Determining the anthropological factors that influence the presence of the plants

To summarize, the intention of the study was to provide custodians of *Cyrtanthus nutans* with an updated distribution pattern, to provide guidelines for management practices that will allow for the successful existence of this species and additionally, to provide scientists with information allowing for the update of current data and possible upgrade of conservation status of this species.

## 1.6 ETHICAL PERMISSION

The Ethics Committee of UNISA, requiring that the researcher should adhere to all the values and principles as expressed by the UNISA Policy and Research Ethics, and have valid authorised permits issued by Ezemvelo KZN Wildlife (Annexure A and B) for the collection of plants where necessary, granted the ethical clearance of this study (Annexure B). Verbal permission from landowners to traverse land for the purpose of data collection and written permission from the land owner where the research was conducted (Mr Hein Potgieter; Annexure C) to apply controlled fires, cut vegetation and place exclusion cages for the purpose of monitoring trial plots on the farm Lerryn 8602 in Dundee, was obtained.

## 1.7 LAYOUT OF THE DISSERTATION

The chapters in the dissertation are arranged as follows:

- Chapter 1 describes *Cyrtanthus nutans* as a species classified as vulnerable within the greater South African biodiversity and the background information that led to the research
- Chapter 2 presents a literature review that provides a background of the study on the *Cyrtanthus* genus
- Chapter 3 introduces the ecological characteristics of north-western, KZN
- Chapter 4 discusses the collection of data and techniques to conduct the study for the population dynamics and autecology of *Cyrtanthus nutans* and the results thereof
- Chapter 5 discusses the methods and techniques to determine the effect climatology, fire and defoliation have on the *Cyrtanthus nutans* population that was undertaken in experimental plots and the results of the findings
- Chapter 6 concludes the findings and conclusions and offers recommendations for future management of *Cyrtanthus nutans* populations

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 INTRODUCTION

Southern Africa south of the three major rivers, Kunene, Okavango and Limpopo Rivers, is known world-wide for the extreme diversity of floral species (Hilton-Taylor, 1996) and according to Scott-Shaw (1999), this area has one of the highest species-rich temperate flora globally with over 24 000 species recorded.

The flora of South Africa's KwaZulu-Natal (KZN) Province has in its own right, a wealth of diversity, with 1258 genera recorded and over 6000 vascular floral species documented. The richness of plant communities is equally diverse and incorporates alpine tundra at 3 300 m above sea level (a.m.s.l.) in the Ukhahlamba (Drakensberg) Mountains through to sub-tropical swamp forests and mangroves along the coastal areas (Scott-Shaw, 1999).

Approximately 13% of the 5260 floral taxa occurring in KZN are either threatened or of conservation concern (SANBI, 2017). The Southern African plant diversity faces several pressures and multiple threats from land transformation and modifications through unsustainable agricultural practices, urbanization and mining, in addition to the uncontrolled spread of alien invasive plants and illegal plant harvesting (Macdonald, 1989; Scott-Shaw, 1999). Almost all ecosystems in southern Africa have been modified or transformed by human activity (Macdonald, 1989).

An increased effort to establish and monitor population trends through inventories, distribution patterns and population dynamics to enable the filling of gaps on the botanical knowledge of threatened species is paramount in reducing threats to flora in the future (Scott-Shaw, 1999).

## 2.2 *Cyrtanthus* GENUS

The *Cyrtanthus* genus was originally described in 1781 by Linnaeus under the *Crinum* genus. Two *Cyrtanthus* species were documented by W. Aiton in 1789 in the “Hortus Kewensis” or the “Catalogue of the Plants Cultivated in the Royal Botanic Garden at Kew” under the *Cyrtanthus* genus. In 1837, William Herbert reviewed the genus, which led to the description of 10 species under the *Cyrtanthus* genus, one under the *Gastronema* genus and one under the *Monella* genus. J.G. Baker took the genus one step further by combining the *Gastronema* and *Cyrtanthus* genus and further sub-dividing *Cyrtanthus* into three sub-genera (*Cyrtanthus proper, Monella* and *Gastronema*) and by 1896, 24 species had been described. In the following years, 17 additional *Cyrtanthus* were described and Dyer named a further three specimens from the South African herbarium that had not yet been described. The total number of species within the genus enumerated 44 by 1939 (Dyer, 1939). By 1984 the number of described *Cyrtanthus* species had risen to 50 (Reid and Dyer, 1984). The *Cyrtanthus* genus currently totals 57 species in Southern Africa, and includes variants and sub-species (SANBI, 2012).

The name *Cyrtanthus* is derived from the Greek words *kyrtos* and *anthos* meaning curved flower (Duncan, 2002). One of the largest genera in the family Amaryllidaceae, *Cyrtanthus* Aiton is restricted to the continent of Africa (Dyer, 1939), and in particular, found in sub-Saharan Africa, in the southern and eastern parts as well as Angola (Dyer, 1939; Snijman, 2003).

## 2.3 BOTANICAL CLASSIFICATION OF *Cyrtanthus nutans*

Botanically, *Cyrtanthus nutans* is classified as follows (Catalogue of Life, 2000);

| | |
|---|---|
| Kingdom: | *Plantae* |
| Phyllum: | Tracheophyta |
| Class: | Liliopsida |
| Order: | Asparagales |
| Family: | Amaryllidaceae |
| Genus: | *Cyrtanthus* |
| Species: | *nutans* |

## 2.4 BOTANICAL DESCRIPTION OF *Cyrtanthus nutans*

The description of *Cyrtanthus nutans*, by Dyer (1954) reads; “globose or subglobose” bulb, up to five cm in diameter, covered with a tunic of brown membrane with a neck of 3-5 cm long. One to three leaves emerge from each bulb slightly after the scape that mature before the fruits ripen, leaves are between 15-20 cm long and 3-7 mm broad. The peduncle is 15-20 cm long and just 3-4 mm in diameter and hollow; there are two linear to lanceolate spathe-valves up to 6 cm in length that become membranous. The pedicels are of unequal length; 1.5-4.5 cm long within the same umbel. The umbel has 2-4 flowers that are nodding when mature. The pale yellow perianth is between 3.5-5 cm long and is divided slightly more than 1/3 its length; with a slightly curved tube that expands gradually from the base to the throat that is approximately 1-1.2cm wide; the lobes are oblong-lanceolate in shape, and about 7mm broad across the base with the outer ones slightly longer than the inner lobes. The stamens are inserted in two rows; the lower three are opposite the outer perianth lobes and inserted 4-5mm within the perianth tube, the filaments are approximately 4-5mm long; the upper three are inserted roughly at the throat of the perianth, opposite the inner lobes; narrowly oblong anthers, are about 8mm long. The style is slightly exerted from the corolla tube and has 3-lobes (National Herbarium, Pretoria, No. 28538).

**Figure 2.1: *Cyrtanthus nutans* in its natural habitat.**

*Cyrtanthus nutans* (Figure 2.1) is commonly known as the “Nodding fire lily” or “Dundee fire lily” (Scott-Shaw, 1999). The species name of *nutans* is derived from the nodding or curved stance of the flowers (McNeil, 1967; Reid and Dyer, 1984).

## 2.5 CONSERVATION STATUS OF *Cyrtanthus nutans* IN SOUTH AFRICA

Hall *et al*. (1980), categorized *Cyrtanthus nutans* as rare in the report on threatened plants of Southern Africa, which, formed part of a world-wide rare species study promoted by the IUCN Threatened Plants Committee. Surveys for this study began in 1974 and covered most of South Africa.

Due to the lack of data for many southern African species, the 1994 IUCN set of categories was not used by Hilton-Taylor (1996) for the Red Data List of Southern African Plants book. Categories from the old IUCN Red Data system were used and *Cyrtanthus nutans* was re-classified under the “Vulnerable” category, where a concern that further decline of a vulnerable-classified species would occur if adverse factors continued to occur. Employing the updated 1994 IUCN Red List Category in his “Rare and Threatened Plants” book, Scott-Shaw (1999) listed *Cyrtanthus nutans* as a lower risk (near-threatened) species.

In the 2009 South African assessments, Raimondo *et al.* (2009) applied the IUCN Red List Categories and Criteria Version 3.1 (2001) and through the work of Scott-Shaw *et al.* (2007) re-assessed *Cyrtanthus nutans* which was again listed as “vulnerable”, with a rating of **VU B1 ab (iii)** where (VU) represents the Vulnerable category, (B1) describes the extent of occurrence to be estimated as less than 20 000 $km^2$, (a) categorizes the range as being severely fragmented or known to exist at no more than 10 locations and (b) describes a continuing observed decline in (iii) area, extent and/or quality of habitat (IUCN, 2012). The global status of *Cyrtanthus nutans* has yet to be assessed for the IUCN Red List but has been listed in the Catalogue of Life (IUCN, 2016; Roskov *et al.* 2017).

The Swaziland Flora Database records *Cyrtanthus nutans*, in terms of the Red Data Book as **EN A1c**, Endangered (EN), where there is a suspected population reduction (A) in terms of a severe decline (50% or more) over the last 10 years (1) based on a decline in habitat, occurrence or occupied area (c) (Dlamini *et al,* 2001).

## 2.6 LEGISLATION FOR THE PROTECTION OF FLORA IN SOUTH AFRICA

Environmental law utilises all forms of legislation to control and manage the unsustainable use and protection of biological resources in South Africa. In particular, Section 24 of the Constitution of the Republic of South Africa (Act 108 of 1996) is dedicated solely to the environment. Repealing the greater part of the Environmental Conservation Act (73 of 1989), the National Environmental Management Act 107 of 1998 (NEMA) provides the framework for decision-making on environmental issues. Following on, the National Environmental Management: Biodiversity Act 10 of 2004 (NEMBA) allows for the management and conservation of South Africa's biodiversity within the NEMA framework.

Within the framework of NEMBA, the South African National Biodiversity Institute (SANBI) was established, a regulatory biodiversity body of species within South Africa. NEMA also brought with it the establishment of Environmental Management Inspectors (EMI) positions, where trained employees of government departments, provincial conservation bodies and municipal departments are authorised to regulate the protection and sustainable use of flora in South Africa.

In addition, key legislation includes CARA (Conservation of Agricultural Resources Act (Act 43 of 1983)) that protects the flora, cultivation of virgin land, utilization of vegetation and controls stocking and grazing capacity of veld, controls and prevents veld fires and the further use of burnt veld. The Environmental Conservation Act (Act 73 of 1989) legislates the agricultural processes that could have a substantial detrimental effect on the environment.

On a provincial level a number of Acts and Ordinances for KZN are in place, namely; Nature Conservation Ordinance 15 of 1974, the KwaZulu-Nature Conservation Act 29 of 1992, and the KwaZulu Nature Conservation Management Act 9 of 1997 (Van der Linde, 2008). Founded in 1947, the Natal Parks Board, promulgated The Nature Conservation Ordinance 15 of 1974, a legislation specifically enacted to protect biodiversity in Nature Reserves and privately owned reserves. Essentially only species listed as “Specially Protected Indigenous Species” were protected through the Ordinance. The KwaZulu Directorate of Nature Conservation was established in 1972 to protect the areas that were not legislated by the Natal Parks Board Ordinance and thus the KwaZulu-Nature Conservation Act 29 of 1992 was enacted which served to control the sustainable use of indigenous species in KZN. The South African democratic elections of 1994 brought about the amalgamation of the two Conservation organisations that became the KwaZulu-Natal Nature Conservation Board, operating as Ezemvelo KZN Wildlife (Ezemvelo KZN Wildlife, 2017).

The KwaZulu Nature Conservation Management Act 9 of 1997 was legislated with specific schedules of both the Ordinance and Conservation Act being repealed. Further changes were made to the Provincial legislation with the KwaZulu-Natal Nature Conservation Management Amendment Act 5 of 1999 with listed protected indigenous species, which included all genera of the Amaryllidaceae family. Most recently the KwaZulu-Natal Environmental, Biodiversity and Protected Areas Management Bill, 2014 was passed. The National and provincial legislations have strengthened the ability of Ezemvelo KZN Wildlife to enforce environmental laws pertaining to species that require protection in the KwaZulu-Natal Province.

## 2.7 GEOGRAPHICAL DISTRIBUTION PATTERNS OF *Cyrtanthus nutans*

*Cyrtanthus nutans* plants were collected for cultivation in 1952 by Dr. L.E. Codd near Vants Drift in the District of Dundee, KZN. Dr Codd reported the occurrence of the plants over an area of about eight kilometres from Vants Drift towards Dundee; he had never observed the species elsewhere. When described, it was reported as abundant in the area. Ten years later it was collected at Piggs Peak, Swaziland on the hills around Mbabane above the Komati River by Gordon McNeil (Reid and Dyer, 1984; McNeil, 1967). Scott-Shaw (1999) described the distribution as a narrow range in the Dundee area and also found in western Swaziland. Distribution of *Cyrtanthus nutans* has not been recorded within a protected area and the full distribution range of *Cyrtanthus nutans* has yet to be documented (Scott-Shaw, 2011: Personal Communication).

## 2.8 THREATS TO POPULATIONS OF INDIGENOUS FLORAL SPECIES

Habitat required by the majority of wild, indigenous species is radically shrinking. Habitat changes in the temperate regions are causing extensive pressure on species due to urban growth, agriculture and commercial forestry (Hall *et al.* 1980). Major land transformations have occurred in the Southern African region due to agricultural practices, such as commercial (irrigation and dry land) or subsistence cultivation, afforestation and invasive tree species, poor land use management (overstocking, overgrazing, incorrect burning practices), urbanization and related infrastructure (road and rail, power and water supply facilities) and mining (Macdonald, 1989). Through time there has been no change and for the period 1999 to 2009, habitat loss (predominantly crop cultivation, urban development), habitat degradation (predominantly overgrazing and deleterious fire regimes) and the spread of invasive alien species were still the three main threats to plant taxa in South Africa (Raimondo *et al.* 2009).

Pressure on the floral populations in Africa through increased human population growth and subsequent need for housing and food resources is disturbingly high. Hall *et al.* (1980) stated that the population of Africa was estimated to double in the last quarter of the 20$^{th}$ Century and South Africa had one of the highest birth rates in the world during the same period. Recent studies have shown that the birth rate in South Africa increased steadily from 2002 until 2009, dropped slightly in subsequent years but has remained static since (Statssa, 2016).

Populations of wild flowers were up until recently, provided with a safe haven against excessive grazing or habitat degradation, simply by existing within a road or railway reserve, when compared with neighbouring agricultural land. Past management practices entailed the mowing of a mere 1-2 metre strip bordering the tarmac for enhanced motorist visibility. Recent times however have brought about the regular clearing of the entire road reserve up to the fence line. This practice has brought about dire consequences for many of our already vulnerable species. Habitat change and erosion has resulted in species not flowering or producing seed and the subsequent demise of pollinators that could eventually affect entire ecosystems. Species affected by these management practices include many Red-data listed species, which are protected under Environmental

Acts and Ordinances, however the lack of compliance by road authorities urgently needs to be addressed (McMaster, 2009). Many road cleared areas are now included as firebreaks in KZN and fences are often non-existent (Van Zyl, 2017: Personal Communication).

Every landowner should, as custodians, be fully aware of the biodiversity existing on their land. Drawing vital information through indicator species to determine the condition and health of the terrain, it will enable them to apply correct management practices in sustaining and preserving biodiversity (McMaster, 2007).

Numerous *Cyrtanthus* species have a limited distribution range or are rare. Habitat destruction and even the vandalism of species are the reasons for the species becoming increasingly threatened; therefore the horticultural cultivation of as many species as possible is required (Reid and Dyer, 1984).

## 2.9 VEGETATION TYPES IN THE DISTRIBUTION RANGE OF *Cyrtanthus nutans* IN SOUTH AFRICA

Over time vegetation in South Africa has been classified utilising various systems. The distribution and classification of South African flora was initiated in 1936 when Pole-Evans (1936) produced the first vegetation map. Following this initial vegetation study, work by Adamson (1938) and by Pentz (1938) allowed progress to be made in the classification of South African floral regions. However, the outstanding work of J.P.H. Acocks commenced in 1945 and the first "Veld Types of South Africa" was published in 1953. It was subsequently reprinted in 1975 and again in 1988 (Acocks, 1988). In the mid-1990's Acocks' vegetation map had become outdated and work by Low and Rebelo (1996) was carried out to simplify, yet provide more detail. Although reprinted in 1998 it was still felt that a more detailed approach was required. This resulted in the implementation of the VEGMAP project and brought about the 2006 work edited by L. Mucina and M.C. Rutherford, "The vegetation of South Africa, Lesotho and Swaziland" (Mucina and Rutherford, 2006).

During the time when Acocks' publication was still in use, the Phillips Bioclimatic Regions (BCR) system was developed for the KwaZulu-Natal province. This system, linked to the work of Acocks, resulted in the province being divided into eleven regions based on climatic characteristics (Phillips, 1973). Camp (1999) developed the Bioresource Groups of KZN by using climate, soil and indicator species to provide guidelines for the optimal utilization of natural resources in the agricultural field.

The *Cyrtanthus* species is generally divided into two groups in terms of its occurrence, growing either in vleis or open grasslands or shade loving species, those that occur in areas on the periphery of forests (McNeil, 1967). *Cyrtanthus* is limited to habitats that have distinct soil types and ecotones or found in isolated gorges (Snijman, 2003). According to Scott-Shaw (1999), *Cyrtanthus nutans* can be found in grasslands and on the margins of vleis near rocks.

## 2.10 GEOLOGY AND SOILS IN THE DISTRIBUTION RANGE OF *Cyrtanthus nutans*

The Tugela Basin, covering some 29000 km$^2$, lies predominantly in the western region of KZN, bordering Lesotho and the Free State Province and reaching down to the coast where the Tugela River meets the ocean north of the town of KwaDukuza (formerly known as Stanger). Divided in to seven ecological regions, the Tugela Basin's largest region is the Interior Basin, which covers most of the Umzinyathi District Municipality. The Interior Basin is moulded by the two major rivers in the region, the Buffalo and Tugela and divided by the Biggarsberg-Helpmekaar-Msinga mountain range. The area is broken up by dolerite formations and middle Ecca sandstone geological features (Edwards, 1967).

The areas north and south of the Biggarsberg range are referred to as partly leached landscapes where the upland soils range from largely leached to soils that show carbonate accumulation. Fersiallitic, ferruginous hardpan and claypan soils can be found, however the fersialitic soils dominate, particularly in the moister parts of the basin. These soils are characteristically friable, porous and permeable with low to medium erodibility due to the variation in their clay content. Weatherable minerals can be found in these saturated soils, although having a natural fertility they still have an acidic to slightly acidic reaction (Edwards, 1967).

The ferruginous hardpan soils, often found in a complex blend with the fersiallitic soils, is characterised by a hardened layer of ironstone or 'ouklip' under the topsoil. In the drier parts of the Interior Basin, the claypan soils can be found. Although originating from the same sedimentary parent material the properties of claypan soils differ. These highly erodible soils are characterized by an acidic topsoil lying above a neutral to alkaline clay horizon, of which illite and mixed illite-montmorillonite are typical soil types, with partly leached topsoils and saturated bases down to the subsoils, they are often saturated with Sodium (Na). Ploughing and overgrazing has led, over time, to severe sheet and rill erosion with these soils (Edwards, 1967).

Upland soils found in the driest parts of the basin that illustrate a lesser degree of weathering are the vertisols or black turf soils, characterized by black clay, the shrinking and swelling of the soil with moisture or lack thereof, results in slickensides and cracks. Due to low permeability, these soils are also highly erodible and ploughing increases sheet and rill erosion (Edwards, 1967).

The lower lying areas of the basin are illustrated by well-defined marshy vleis with neutral to alkaline hydromorphic soils that are characterised by dark grey topsoils, covering clay subsoils with saturated bases. Run-off and seepage from higher lying areas combined with highly erodible soils in the lower areas, has resulted in severe gully erosion, forming dongas that have eventually infringed into the adjoining upper areas (Edwards, 1967).

## 2.11 CLIMATOLOGY IN THE DISTRIBUTION RANGE OF *Cyrtanthus nutans*

Northwest KZN is largely characterized by a relatively high summer rainfall, which varies between 700 to 800 mm annum$^{-1}$, and altitudes between 900 and 1400 m a.m.s.l. Erratic rainfall is experienced with frequent periods of moisture stress. Mild summer conditions are followed by regular, severe frosts in the winter, which results in a relatively short growing season. Frequent strong, cold winds depress winter temperatures and at higher altitudes snow is occasionally experienced (Phillips, 1973).

## 2.12 SIGNIFICANT ROLE OF FIRE IN SEEDLING RECRUITMENT

Most ecosystems are exposed to fire as a natural element, and most plants utilize fire as a strategic tool in their ability to survive. Burned grasslands provide a greater visual impact of bright flowers against the blackened habitat for pollinator attraction as well as the reduction in moribund material enabling easier germination of seed in soils, and a reduction in competition from neighbouring plants for plant development. *Cyrtanthus*, a predominantly fire dependant species, has seed that is known to remain dormant for numerous years if the interval between fires is extensive. However not all *Cyrtanthus* species are stimulated by or reliant on fire to emerge or flower (McMaster, 2008) as only certain *Cyrtanthus* species can be described as 'fire lilies', others are pollinated by insects and birds, this being species specific (McMaster, 2007).

Fire is an important tool to remove moribund grass cover, thereby increasing insolation, resulting in higher soil temperatures, and the subsequent flowering of populations in a short space of time after a burn (Gordon-Gray and Wright, 1969). In the fynbos vegetation of the Western Cape, 'fire lilies' (*Cyrtanthus* spp) flower after fire, irrespective of the season (Brown and Le Maitre, 1990) and the flowering of *Cyrtanthus ventricosus* is stimulated by smoke (Keeley, 1993). *Cyrtanthus ventricosus* is stimulated by fire to flower, although most likely triggered by environmental changes (soil temperature deviations) and not directly through damage to leaves or apical buds by heat (Huggett, 2004).

Although tolerant to fire, *Cyrtanthus nutans* flowers readily in unburnt grassveld (Dyer, 1954). Similar to *Cyrtanthus nutans*, *Cyrtanthus galpinii* flowers at the end of winter when grasslands are at their driest. If burning occurs at flowering or seed development time, then an entire season of new flowers will be lost. Fires from May to early July provide the best conditions for flowering of this species. Plants occurring in the burnt areas, where previously dense grass cover occurred, as well as plants in sparsely grassed areas flowered well. However the areas where there has been no fire and grass cover was dense, plants had not flowered at all. Optimum flowering occurred when early winter fires took place (Craib, 2004).

## 2.13 HERBIVORY AND ITS EFFECTS ON SEEDLING RECRUITMENT

Land-use changes, causing fragmentation of areas, may affect wildlife population sizes and in turn exacerbate the decline of rare and endangered wildflower populations. Deer and insects were found to damage a higher number of emerging plants than rodents in areas where small *Lilium superbum* populations (1 - 2 plants) occurred as opposed to more densely populated areas (3 - 20 plants). Therefore consideration should be taken to protect rare perennial wildflowers from herbivores in declining or re-introduced populations (Fletcher *et al,* 2001). The impact on a species' abundance, its dynamics, distribution patterns and overall survival through herbivory of various consumers, is often not determined to its full extent (Maron and Crone, 2006). With *Cyrtanthus galpinii*, Craib (2004) suggested that shorter grass which had been grazed by animals could benefit the species over the long term.

## 2.14 POLLINATION, FLOWERING AND SEED DEVELOPMENT OF *Cyrtanthus* SPECIES

Brown and Le Maitre (1990) noted that pollination by insects or birds, 12 days after the emergence of flowers of fire dependant *Cyrtanthus ventricosus*, was still inefficient, as low numbers of seed were produced from the average five flowers per plant. This indicated that reproduction viability was low under natural conditions if fires were as infrequent as every 10-15 years.

Similar to other species in the Amaryllidaceae family, the *Cyrtanthus* flowering period is short-lived due to its reliance on rainfall or stimulation by fire and when not in flower can easily be overlooked as the narrow but distinctive leaves are often not present (McNeil, 1967). Flowering time of *Cyrtanthus nutans* is late August to October (Reid and Dyer, 1984). The germination of *Cyrtanthus* seeds normally occurs when the initial summer rains arrive, particularly in short grasslands (Craib, 2004).

## 2.15 CONCLUSION

Literature references suggest that in recent years, no additional research has been conducted on the *Cyrtanthus nutans* species. Basic information in the form of habitat descriptions and distribution patterns has been documented; however only limited information on the influence of ecological factors on the species could be sourced. Scott-Shaw (1999) stated that the monitoring of populations was an essential requirement for this particular species. Regular monitoring of biodiversity is essential for the success of any species. Renewed awareness by landowners together with the improved environmental legislations could be the influential factor required to change the conservation status of the species.

# CHAPTER 3

# STUDY AREA

## 3.1 INTRODUCTION

As documented by Scott-Shaw *et al*. (2007), *Cyrtanthus nutans* occurs in the Dundee area of KwaZulu-Natal Province (KZN) and was found at five known locations. The extent of occurrence during the current study was unknown. In addition to the referred locations by Scott-Shaw *et al*. (2007), areas further afield were traversed in an endeavour to locate additional sites of occurrence.

Two investigations were undertaken to achieve the objectives of this study. The first investigation was to conduct the study of population dynamics and autecology of *Cyrtanthus nutans* in the greater Dundee area. The second investigation was to conduct an experiment to investigate the effect of climatology, fire and defoliation on the emergence, recruitment and survival of *Cyrtanthus nutans*.

## 3.2 STUDY AREA

Dundee is located in the north-western region of the KZN province, south of the Biggarsberg mountain range and falls under the jurisdiction of Umzinyathi District Municipality (DM), situated in close proximity to adjoining District Municipalities of Uthukela and Amajuba. Although areas within the Amajuba DM were traversed, no *Cyrtanthus nutans* sites of occurrence were located.

The area for the first investigation incorporated the Umzinyathi DM and Uthukela DM and their corresponding Local Municipalities, namely;

- Umzinyathi DM with its two Local Municipalities (Figure 3.1);
    - Endumeni LM
    - Msinga LM
- Uthukela DM with its Local Municipalities (Figure 3.2);
    - Indaka LM


**Figure 3.1: Umzinyathi District Municipality indicating the four Local Municipalities (www.municipalities.co.za).**


**Figure 3.2: Uthukela District Municipality indicating the five Local Municipalities (www.municipalities.co.za).**

The site chosen for the small plot experiment (the effects of fire and defoliation) was situated on the farm, Lerryn 8602, a large scale dairy farm “Drafstap Boerdery”, located approximately two kilometres from the KZN Department of Agriculture & Rural Development’s Dundee Agricultural Research Station (Figure 3.3). A small section of the farm is fenced off to limit access by cattle into the marsh (vlei) and eroded area (donga). A small population of approximately 300 *Cyrtanthus nutans* plants occurred at the site.

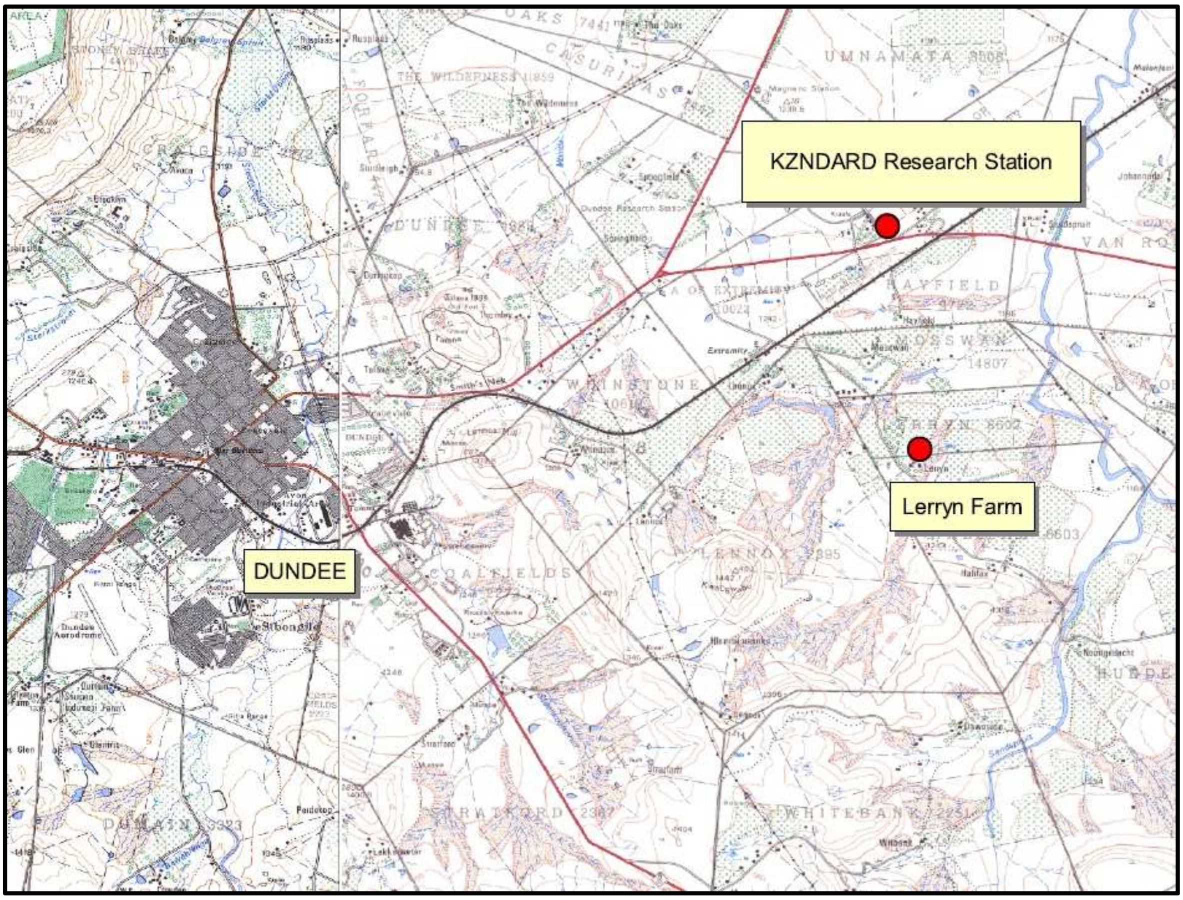


**Figure 3.3: Dundee town in relation to the experimental plots and Research Station.**

Areas traversed during the mapping of *Cyrtanthus nutans* included recreational facilities, government, municipal and privately owned land, district and municipal road networks, railway servitudes and water courses.

## 3.3 CLIMATOLOGY

Climatological data was obtained from the Agricultural Research Council (ARC) automated weather station based at the Dundee Agricultural Research Station

(DARS) of the KZN Department of Agriculture and Rural Development (KZNDARD) (S28.1375°, E30.3176°). The climatology of Dundee is classified as semi-arid with hot summers and cool, dry winters. The mean annual rainfall is 759 mm (minimum 428 mm, maximum 1 241 mm), with rainfall occurring mainly during summer. For the period 2012-2016, mean maximum and minimum summer temperatures (November to April) were relatively high at 26.86 °C and 13.67 °C respectively and mean maximum and minimum winter temperatures cold, namely; 23.39 °C and 5.96 °C respectively (ARC Weather Station, Dundee, 2016). Incidences of frost can occur during winter months.

### 3.3.1 Rainfall

The long term annual rainfall for Dundee, KZN for the period 1968-2016 was used for the purpose of the study. The long term mean annual rainfall for the area is 749 mm. Over the 49 year period of data records, a linear regression indicated that the mean annual rainfall has increased compared to records from 1968. The highest recorded rainfall for the 49 year period was in 2013/14 (1 241 mm) and lowest was in 2014/15 (428 mm) (Figure 3.4).

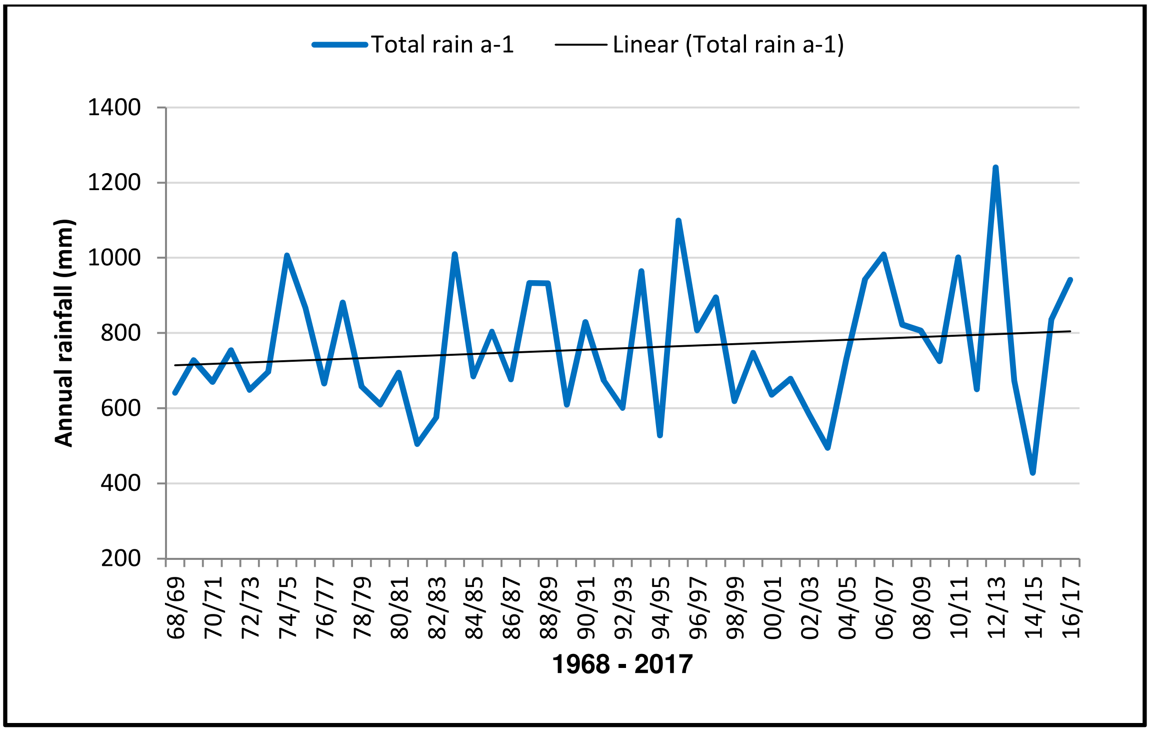


**Figure 3.4: Long term mean annual rainfall for Dundee, KwaZulu-Natal for the period 1968-2017.**

### 3.4 GEOLOGY AND SOILS

The soils in the area are based mainly on *in situ* weathering within the landscape. The geology of the area is generally underlain by rocks of the Karoo Sequence, Ecca Group and the Vryheid Formation which consists of sandstone, shale (grey micaceous), interspersed by coal seams; intrusive dolerite dykes and sills are also found (Department of Mineral and Energy Affairs, 1988).

Various soil types were recorded at the soil sample sites, which include Arcadia, Avalon, Hutton, Glenrosa, Katspruit, Longlands and Rensburg (Soil Classification Working Group, 1991).

### 3.5 VEGETATION

According to Acocks (1988) the vegetation within the study area are characterised by four vegetation types, namely;

- Natal Sour Sandveld (Veld type 66)
- Southern Tall Grassveld (Veld type 65)
- Highland Sourveld (Veld type 44)
- Valley Bushveld (Veld type 23)

The distribution of *Cyrtanthus nutans* plants occurred in only three of the vegetation types, and was predominantly found in Natal Sourveld and Southern Tall Grassveld, with fewer plants in the Highland Sourveld and no plants in the Valley Bushveld.

On a magnified scale, based primarily on climatology and vegetation and utilising a benchmark system, the Bioresource Groups (BRG) of KZN incorporates four BRG within the study area (Camp, 1999), namely;

- Dry Highland Sourveld (BRG 9)
- Moist Tall Grassveld (BRG 12)
- Sour Sandveld (BRG 14)
- Mixed Thornveld (BRG 18)

Dry Highland Sourveld (BRG 9) occupies the higher lying western and central portion of KZN, including the Helpmekaar area. This BRG is described as a low closed grassland with grass species seldom reaching a height in excess of 0.5 m. Droughts are frequent for this group and the annual rainfall is recorded as between 620 mm and 816 mm with the lower extremes found in the Newcastle area. Snow is infrequent and the mean annual temperature is between 12.9 °C to 15.9 °C. Fire plays a major role in this group, maintaining it as grassland, without which the area would become dominated by shrub and bush (Camp, 1999).

Moist Tall Grassveld (BRG 12) is described as an area with a slightly higher mean annual rainfall (712-805 mm) with three to four ecologically dry months. The mean annual temperature varies between 15.3 °C to 18.9 °C and occasional drought periods occur during the summer, frosts are moderate to severe in winter and hailstorms are experienced. As a widely distributed BRG throughout KZN, the Moist Tall Grassveld BRG is represented by its indicator species, *Hyparrhenia hirta* (Thatch grass) which is found in abundance together with the paperbark thorn, *Vachellia sieberiana* (Camp, 1999).

Sour Sandveld (BRG 14) is widespread and a dominant BRG in the Dundee/Newcastle/Vryheid area with a sub-group in the Wasbank area. The mean annual rainfall varies between 645 mm and 737 mm and the mean annual temperature is between 14.7 °C and 17.3 °C. An area characterised by sparse tall grassveld, with woody encroachment in mismanaged areas. This area occurs on shallow, sandy, poorly drained soils and is dominated by the grass species *Tristachya leucothrix* and *Digitaria tricholaenoides,* particularly on deeper sandy soils, with *Aristida congesta*, *Cynodon dactylon* and *Microchloa caffra* on shallower soils (Camp, 1999). Although Mixed Thornveld (BRG 18) occurs as a transitional band between Dry Highland Sourveld, Moist Tall Grassveld and Sour Sandveld, no *Cyrtanthus* populations were found there (Camp, 1999).

# CHAPTER 4

# POPULATION DYNAMICS OF *Cyrtanthus nutans*

## 4.1 INTRODUCTION

The population dynamics and autecology of *Cyrtanthus nutans* in North-western KwaZulu-Natal (KZN) were assessed in this chapter. Due to the expanse of the area and limitations of plant characteristics (emergence and flowering times), plants could only be recorded when in flower during spring months (September and October); the period of identification and mapping was therefore restricted to a few weeks each year.

## 4.2 AIM

The aim of this part of the study, in achieving the research objectives, was to determine the population dynamics and autecology of *Cyrtanthus nutans* and to conduct the following;

- Record the co-ordinates, topography, altitude, slope percentage and population numbers for all *Cyrtanthus nutans* sites. Note the presence or absence of grazers and fire activity and any anthropogenic factors at each site.
- Assess the veld condition at significantly populated sites of *Cyrtanthus nutans* within its distribution range.
- Determine the soil attributes at significantly populated sites of *Cyrtanthus nutans* within the distribution range in order to quantify the soil environment.

## 4.3 MATERIALS AND METHODS

### 4.3.1 Methods and techniques

In this study, various research methods were applied in order to achieve the research objectives to determine the population dynamics and autecology of *Cyrtanthus nutans*, as set out below.

### 4.3.2 Site identification and occurrence

Occurrence sites that were informally documented by the author (as a KZN Wildlife employee) during the period 2006 - 2012, were revisited and documented in 2013. For the period 2013 - 2016, new sites were investigated during the spring flowering season on an annual basis. Any sites that were found to be duplicated were excluded from all data sets. Only neighbouring areas where flowering plants had not previously been recorded were documented if emergence of new flowering plants had taken place.

All sites were accessed by provincial and municipal (tarmac) or secondary (gravel) roads or by foot. As a site of occurrence was identified, the site was appropriately named according to the landowner/company name or business/recreation activity that could identify the area.

The co-ordinates for each site were recorded in the form of latitude and longitude using a Garmin eTrex 10® Global Positioning System (GPS). All co-ordinates were plotted using ArcGIS® (ArcGis 9.3.1; Esri software)

### 4.3.3 Topography - terrain unit, altitude and slope

The topography of each site was documented according to the terrain unit, altitude and slope. Five terrain units are recognised as per the Land Type Survey (Smit *et al*. (1995), namely: Crest (unit 1), scarp (unit 2), midslope (unit 3), footslope (unit 4) and valley bottom or floodplain (unit 5) (Figure 4.1). The altitude, in metres above mean sea level (a.m.s.l.) was recorded using the Garmin eTrex 10®. In addition, the slope for each site was estimated and recorded.

### 4.3.4 Population count

The number of flowering plants at each site was recorded and a total number of flowering plants for each area calculated. The number of flowering plants at each site was recorded once only during the period 2013-2016. Any co-ordinates that were a duplication or possible duplication were discarded. Therefore a "snapshot" population for each site was determined.

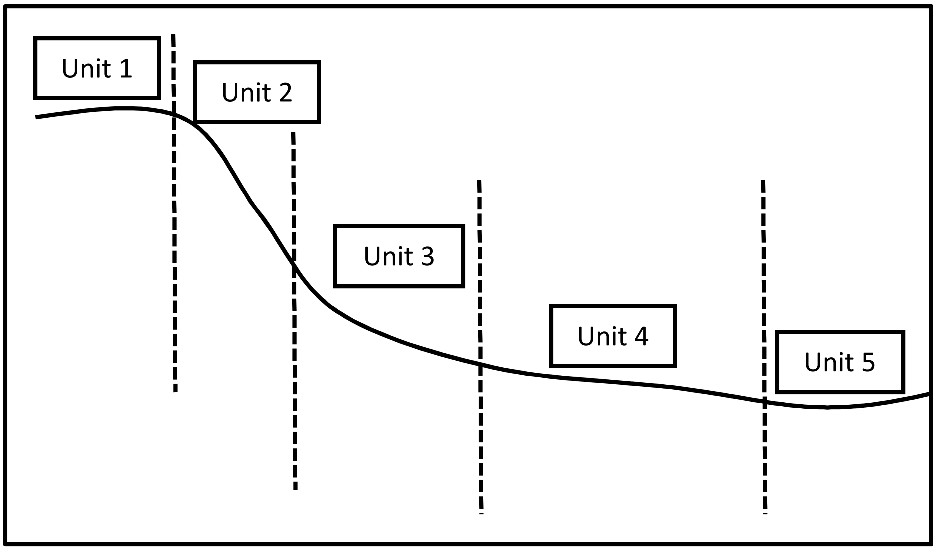


**Figure 4.1: Terrain units of a slope - adapted from Smith (1999).**

### 4.3.5 Presence/absence of fire

The presence or absence of fire in burnt or unburnt veld was recorded at each of the sites of occurrence. Where burning had recently occurred at a site and the grass had seasonal growth, an estimate of when the burn took place was recorded (winter/spring). The site was observed as a whole unit; therefore if the main portion was burnt with patches of unburnt grass that occurred within the site, the site was noted as burnt.

### 4.3.6 Herbivores

Herbivore presence was recorded for each of the sites. This included all agricultural stock, indigenous game species or insect species.

### 4.3.7 Land use

Human related activities such as pedestrian thoroughfares, mountain bicycle tracks or informal vehicular tracks were recorded for each of the sites of occurrence. In addition, land use, agriculture type and herbivore access was recorded for their possible influence on its *Cyrtanthus nutans* populations.

### 4.3.8 Negating factors

Activities that had either a positive or negative influence on the survival of the *Cyrtanthus* species were recorded for this study. Man-induced and herbivorous activities directly responsible for loss of plants were photographically recorded.

### 4.3.9 Geology and soils

Sites presenting significant populations of *Cyrtanthus nutans* were selected for soil samples. Soil analysis was limited to eight sites due to time and financial constraints. All sites were perceived to be historically undisturbed in terms of changes in soil profiles due to agricultural practices. The terrain units for each site were recorded. In addition, parent rock was identified and documented if exposed at the site.

Using a Dutch auger, Sample A (topsoil, excluding organic material) was sampled at a depth of 0-30 cm and Sample B (sub-soil) at a depth of 30-60 cm. Samples were taken and a representative sample was placed in a soil laboratory box (see data analysis 4.3.11). The analysis of the soil samples was carried out in accordance with standard laboratory practice (Manson and Roberts, 2001). Soil analysis included the following soil analytical results;

- Phosphorous (P mg $L^{-1}$)
- Potassium (K mg $L^{-1}$)
- Calcium (Ca mg $L^{-1}$)
- Magnesium (Mg mg $L^{-1}$)
- Sample density (mg $L^{-1}$)
- Exchangeable acidity (cmol $L^{-1}$)
- Total cations (cmol $L^{-1}$)
- Acid saturation (%)
- pH (KCl)
- Zinc (Zn mg $L^{-1}$)
- Copper (Cu mg $L^{-1}$)
- Manganese (Mn mg $L^{-1}$)
- Clay content (%) estimation
- Organic carbon (%) estimation
- Nitrogen (N) (%) estimation
- C:N ratios

### 4.3.10 Vegetation

Veld condition assessments were undertaken at 17 sites, based on the presence of significant *Cyrtanthus nutans* populations and veld utilisation (grazing capacity and veld management practices). Veld condition was determined using various factors, namely species composition, palatable species vigour, basal cover and soil surface condition. Taking into consideration that species composition is the only factor that can be determined objectively, the veld condition assessment was therefore based on this. The condition of a veld is assessed by comparing its species composition with that of a benchmark site that is the most productive of its kind within the BRG. Each grass species is classified under its ecological grouping according to its response to grazing and fire (defoliation). In addition, a grazing value is rated according to its acceptability to grazers in terms of palatability and digestibility as well as its potential to produce during the growing season (Camp, 1999).

In accordance with the natural distribution of the *Cyrtanthus nutans* plants within a site, a random path was traversed through each veld condition assessment site, using a sharp stick, of approximately 1.2 m in length, and 50 spike-point observations were made. The nearest grass species to the point was identified and recorded. The total number of each species was transcribed onto a veld assessment condition form (Annexure D) where the overall veld condition was calculated.

#### 4.3.11 Data analysis

All data was captured into Microsoft® Excel (2010) and analysed. Co-ordinates for all sites of occurrence, soil samples and vegetation were captured into ArcGIS® (ArcGis 9.3.1; Esri software) and overlain with 1:50 000 topographical maps and BRG vegetation maps (Ezemvelo KZN Wildlife, 2009).

The analysis of the soil samples was carried out at the Cedara Soil Laboratory of the Department of Agriculture and Rural Development (KZN) (DARD (KZN)), which is a fully accredited laboratory, in accordance with standard laboratory practice (Manson and Roberts, 2001).

## 4.4 RESULTS AND DISCUSSIONS

### 4.4.1 Site identification and occurrence

The majority of *Cyrtanthus nutans* plant populations were found to occur on road and railway servitudes, peripheral areas of agricultural lands and urban developments, forming distinct linear distribution patterns (Figure 4.2). The fragmentation of *Cyrtanthus nutans* areas was apparent due to land transformation throughout the region. Distribution was dominant in the eastern and south eastern areas of Dundee.

Of the three District Municipalities (DM) originally traversed from 2013 to 2016, only two (Umzinyathi DM and Uthukela DM) were found to be populated with *Cyrtanthus nutans* plants. No plants were found in the southern portion of Amajuba DM near the Umzinyathi municipal boundary. In Umzinyathi DM, plants were only located in two of the four Local Municipalities (LM), namely; Endumeni LM and Msinga LM. In Uthukela they were only located in the Indaka LM near Wasbank. The region where plants were found extended over some 1 450 km$^2$.

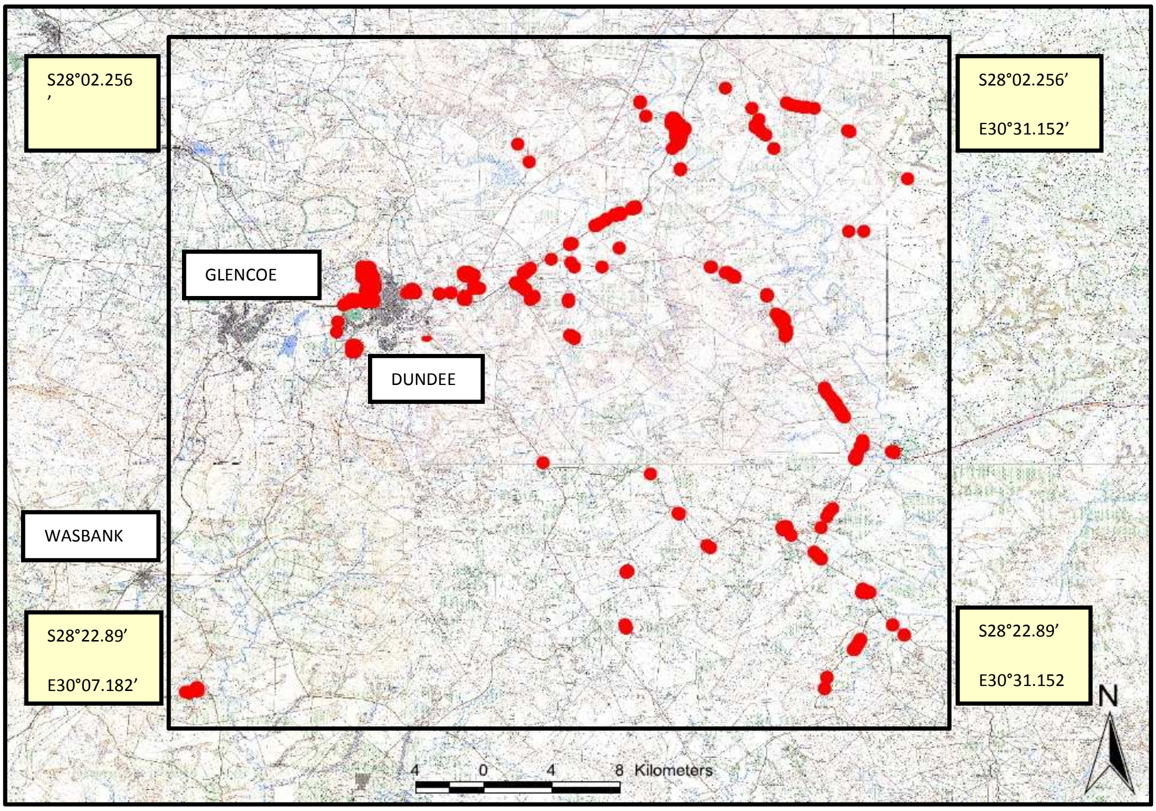


**Figure 4.2: Range and distribution of *Cyrtanthus nutans* in KwaZulu-Natal.**

Throughout the region, 27 separate sites, varying in extent, were identified and separated into five main areas (Figure 4.3), namely;

- Dundee Central Business District (CBD)
- Dundee North-East (DNE)
- Dundee East (DE)
- Rorke's Drift (RD)
- Wasbank (WB)

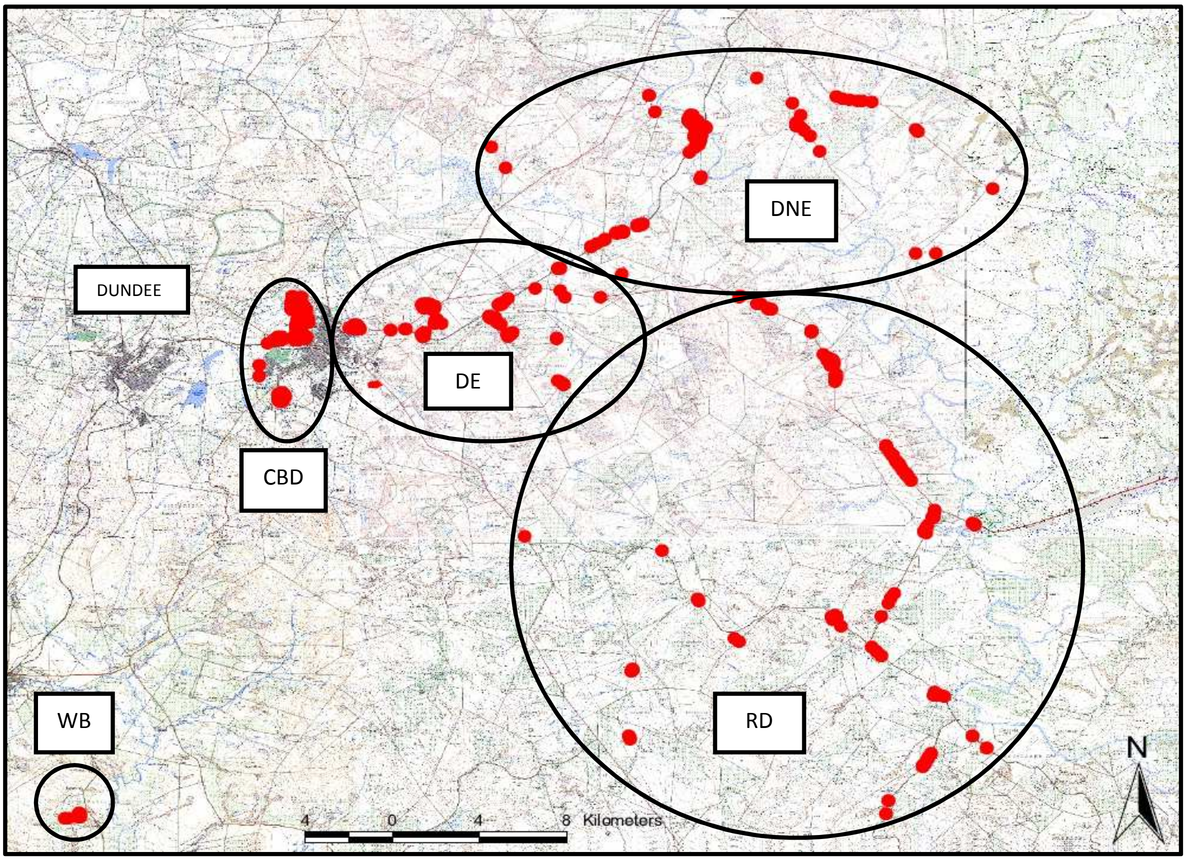


**Figure 4.3: Five main areas of *Cyrtanthus nutans* occurrence.**

Each site with its descriptive name was designated a central co-ordinate for ease of reference (Table 4.1).

**Table 4.1: Sites of occurrence and geographical coordinates**

| Main areas | Site names | Central co-ordinates of sites | |
|---|---|---|---|
| | | South | East |
| CBD | Aerodrome | 28° 11.21' | 30° 13.09' |
| | Dundee Junior School | 28° 09.29' | 30° 13.50' |
| | Meer | 28° 09.66' | 30° 13.04' |
| | Showgrounds | 28° 09.64' | 30° 13.56' |
| | RTI | S8° 09.73' | 30° 12.88' |
| | Smith Street | 28° 08.85' | 30° 13.52' |
| | Strathmore | 28° 10.37' | 30° 12.53' |
| DE | Consol | 28° 10.88' | 30° 15.38' |
| | Ingudlane Farm | 28° 09.59' | 30° 16.58' |
| | Ingudlane Reserve | 28° 09.22' | 30° 16.88' |
| | Lennox Railway | 28° 08.75' | 30° 18.48' |
| | Lerryn Farm | 28° 09.53' | 30° 18.77' |
| | Peacevale | 28° 09.45' | 30° 15.77' |
| | Springfield | 28° 08.80' | 30° 16.68' |
| | Talana | 28° 09.34' | 30° 14.93' |
| DNE | Anton | 28° 04.54' | 30° 18.30' |
| | District Road | 28° 04.03' | 30° 25.94' |
| | Frik | 28° 03.31' | 30° 27.13' |
| | Malonjeni Station | 28° 06.86' | 30° 21.40' |
| | Triple C land | 28° 05.36' | 30° 23.45' |
| | Tayside | 28° 04.09' | 30° 23.37' |
| RD | Helpmekaar | 28° 21.05' | 30° 28.93' |
| | Muller | 28° 18.61' | 30° 21.70' |
| | Nquthu Road | 28° 10.08' | 30° 26.48' |
| | Nxala Road | 28° 16.52' | 30° 28.27' |
| | Rorke's Drift Road | 28° 16.65' | 30° 23.34' |
| WB | Kameelkop | 28° 22.49' | 30° 07.93' |

**CBD Area**

The CBD consists predominantly of industrial and urban development, with large tracts of Municipal-owned land that is utilised for recreational and agricultural purposes (mainly cattle grazing) (Figure 4.4). In terms of *Cyrtanthus nutans* populations, areas of significance within the CBD include an area in the south, called the Aerodrome (Figure 4.5). Up until 2016, the Aerodrome was utilised throughout the year for cattle grazing and resource use (grass cutting). In 2016, the area was fenced off and no further grazing is permitted. In addition to livestock grazing, the area is utilised for the annual horse racing event in July. Other areas of importance included natural veld interspersed with small weathered dolerite outcrops in the northern section of town between housing developments, schools and recreational facilities where cattle are grazed. The mean elevation for this area is 1 242 m above mean sea level (a.m.s.l.).

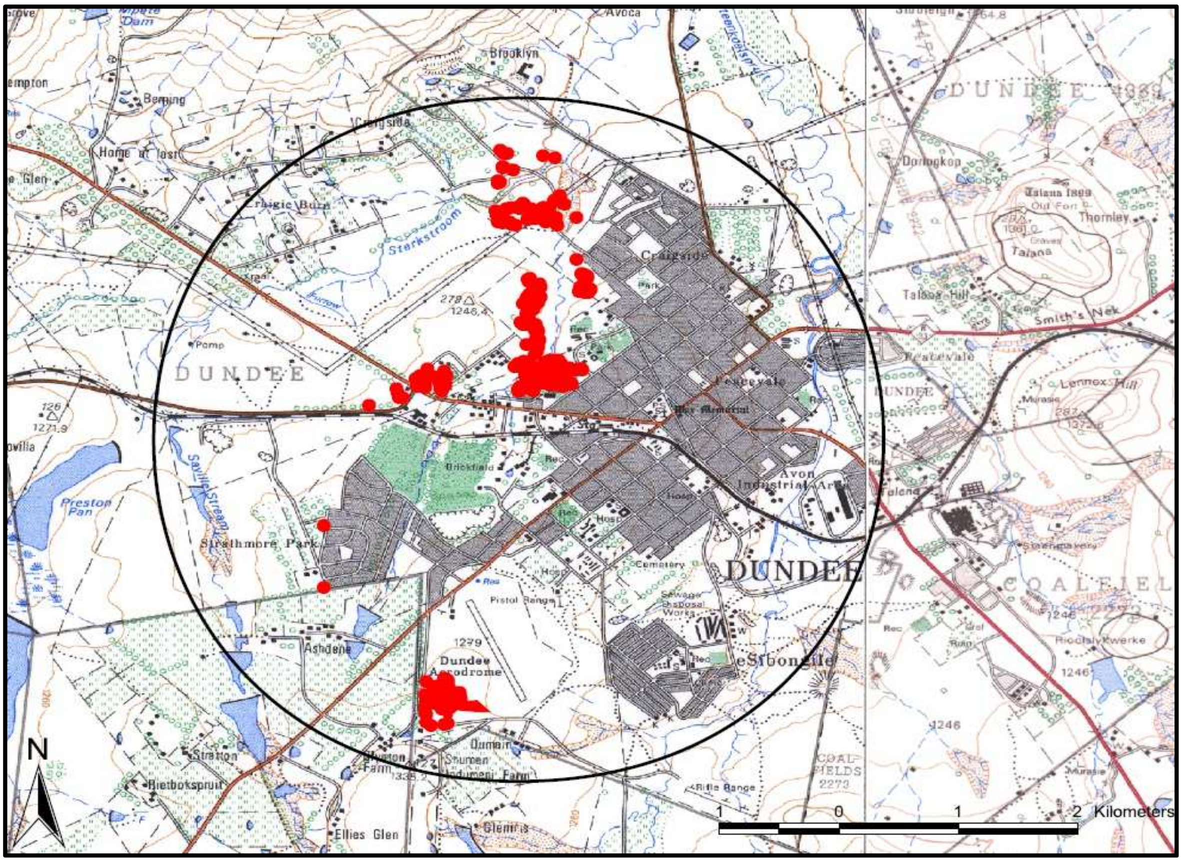


**Figure 4.4: Distribution points of *Cyrtanthus nutans* in the Central Business District area.**

**Figure 4.5: Flowering *Cyrtanthus nutans* on the racetrack at the Aerodrome, CBD area.**

**DE Area**

The second area, close to the CBD is referred to as Dundee East and is an area predominantly characterised by flat tracts of land with intermittent rocky dolerite outcrops. DE comprises primarily privately owned small scale game farms and agricultural land for livestock utilisation. In addition, large areas of land are also owned by industrial and mining companies and municipalities (Figure 4.6).

Areas of significance in terms of *Cyrtanthus nutans* populations included Municipal land below the Talana Museum utilised for communal stock grazing and as pedestrian thoroughfares into Dundee town, natural veld for stock grazing and Transnet railway line servitudes (Figure 4.7). Mean elevation for this area is 1 159 m (a.m.s.l.).

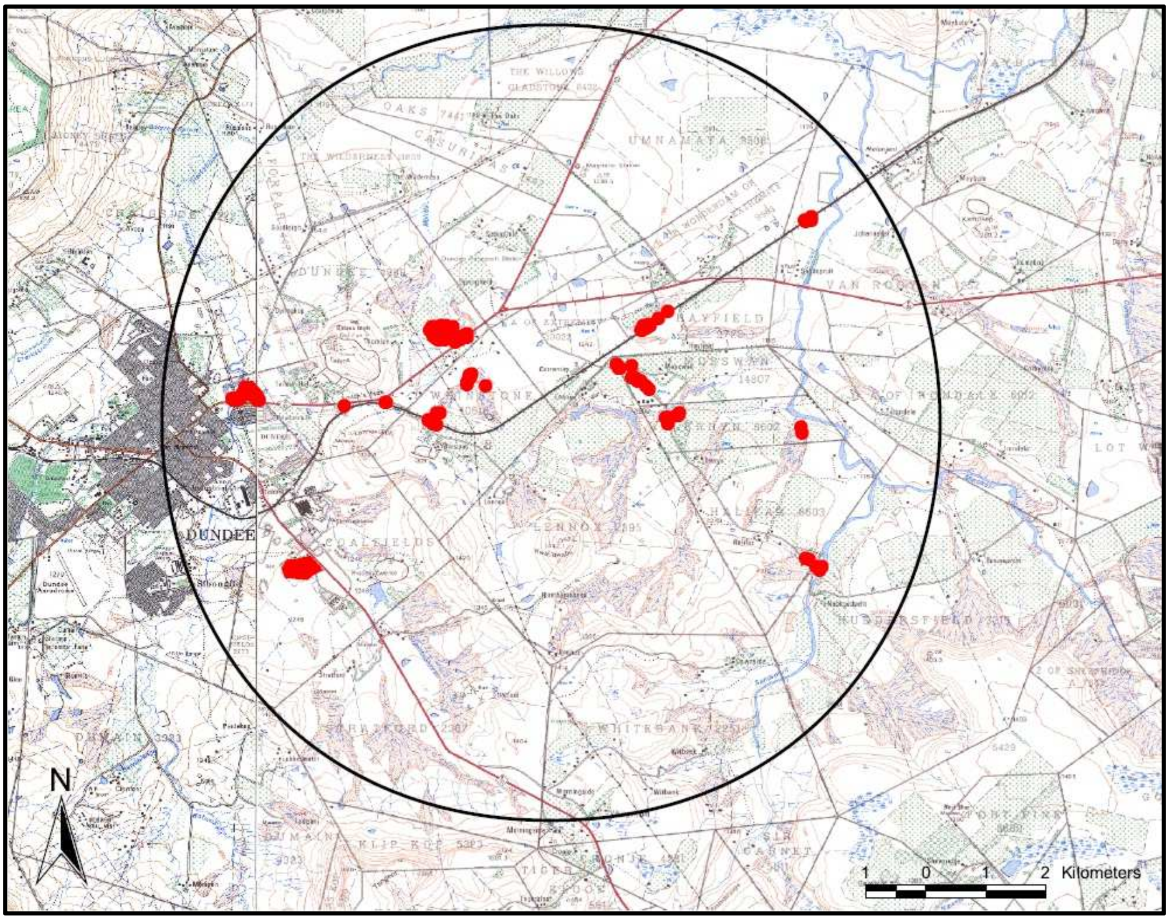


**Figure 4.6: Distribution points of *Cyrtanthus nutans* in Dundee East area.**

**Figure 4.7: *Cyrtanthus nutans* populations in the railway servitude.**

### DNE Area

DNE is an area situated in close proximity to the confluence of the Buffalo River and Sandspruit stream. A slightly undulating area with small dolerite outcrops, this area consists predominantly of privately owned cattle farms. Areas of richness in terms of *Cyrtanthus nutans* populations included the Tayside area and the Transnet railway line servitudes and gravel road servitudes. The mean elevation for this area is 1 227 m (a.m.s.l.) (Figure 4.8).

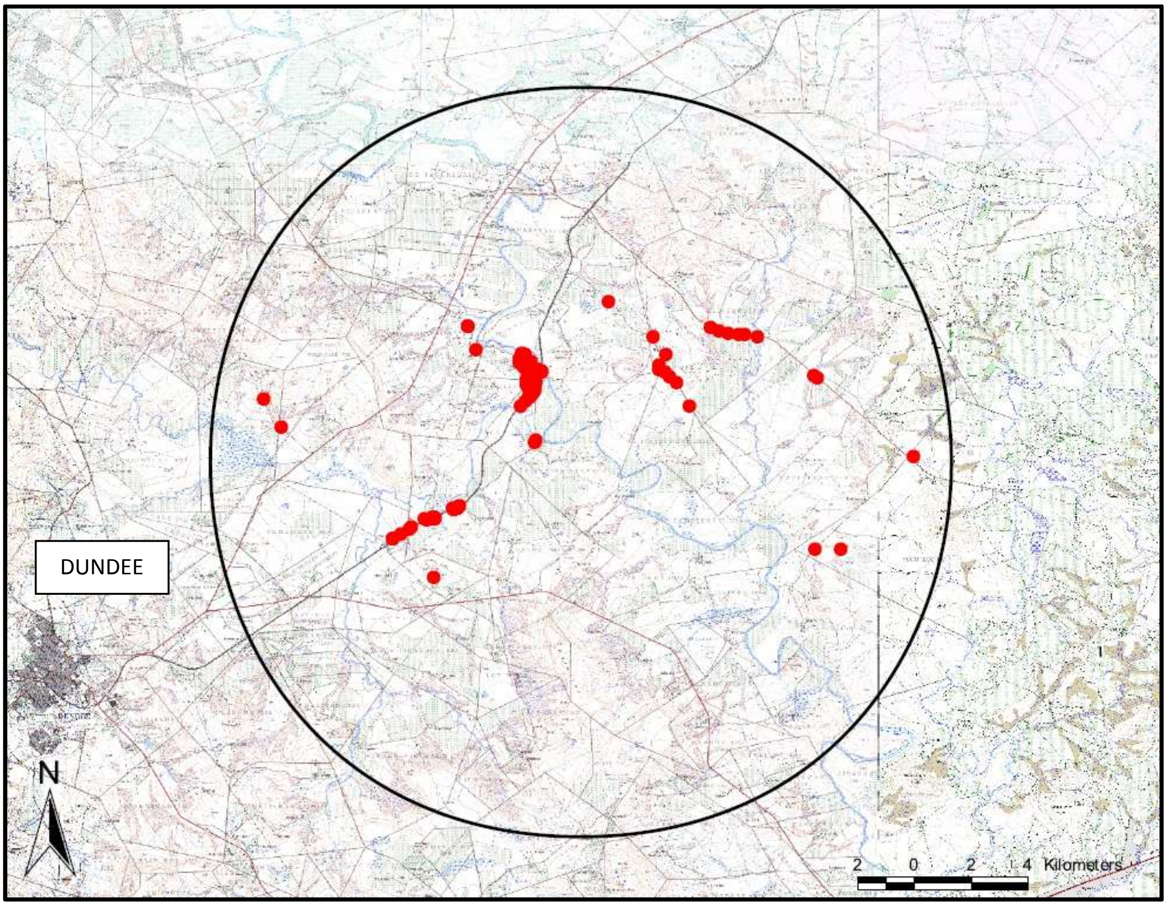


**Figure 4.8: Distribution points of *Cyrtanthus nutans* in Dundee North-East area.**

### RD Area

Rorke's Drift is the largest of the *Cyrtanthus nutans* distribution areas. An extensive area where plants were found extending from the northern region close to the Dundee Agricultural Research Station (DARS) by the Madikazi stream, a tributary of the Buffalo River and occurred in a south easterly direction towards Helpmekaar and Rorke's Drift. Dominated by privately owned mixed cattle and game farms this area ranges in topography from mountain passes to hygrophilous grasslands. With a large variation in altitude (1 087-1 459 m (a.m.s.l.), the mean elevation for this area is 1 205 m (a.m.s.l.) (Figure 4.9).

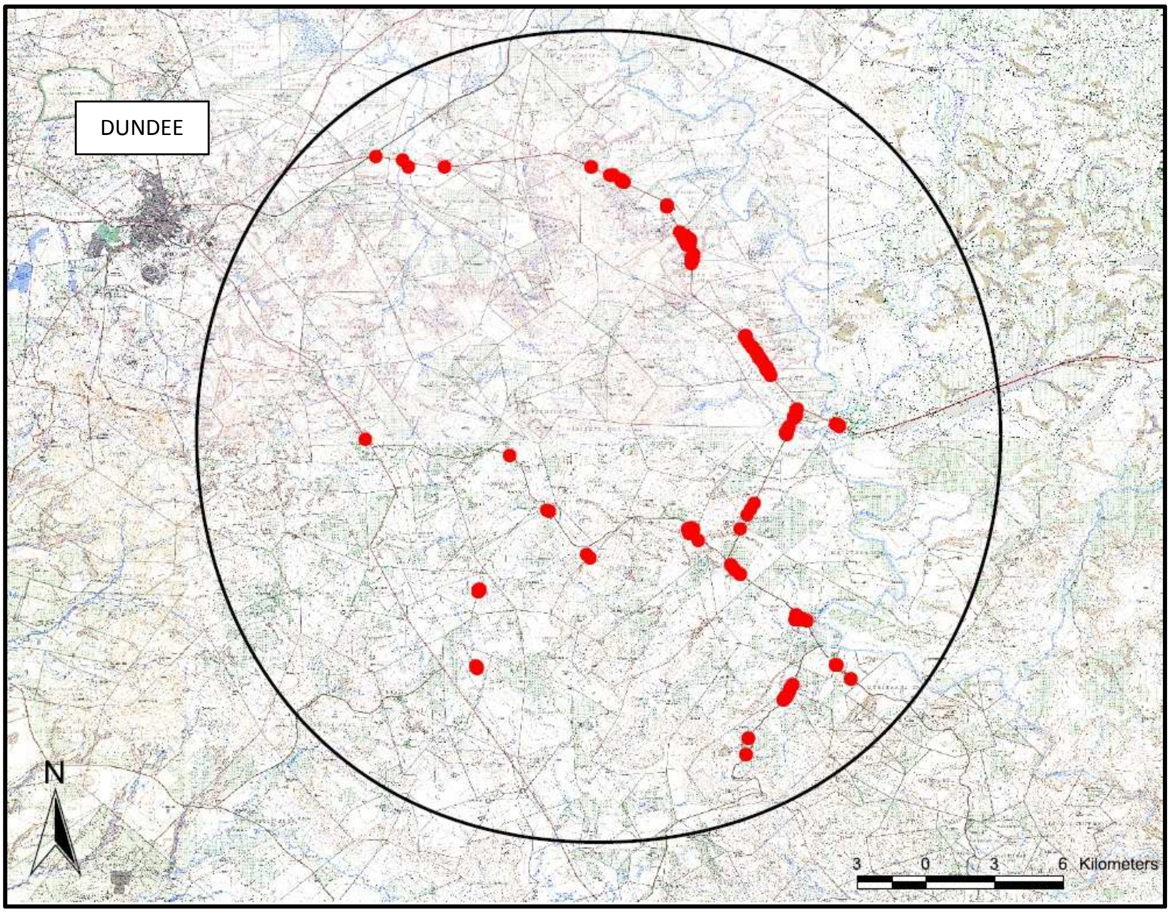


**Figure 4.9: Distribution points of *Cyrtanthus nutans* for the Rorke's Drift area.**

### WB Area

Wasbank area, an outlier in terms of the *Cyrtanthus nutans* distribution, is isolated with a small population representing the species. The area is dominated by sparsely populated settlements that are practicing communal grazing and are interspersed with privately owned cattle and game farms. The altitude is the lowest for the region with a mean elevation of 1 037 m (a.m.s.l.) The *Cyrtanthus nutans* site occurred on a community-owned game farm in a historically eroded area (Figure 4.10).

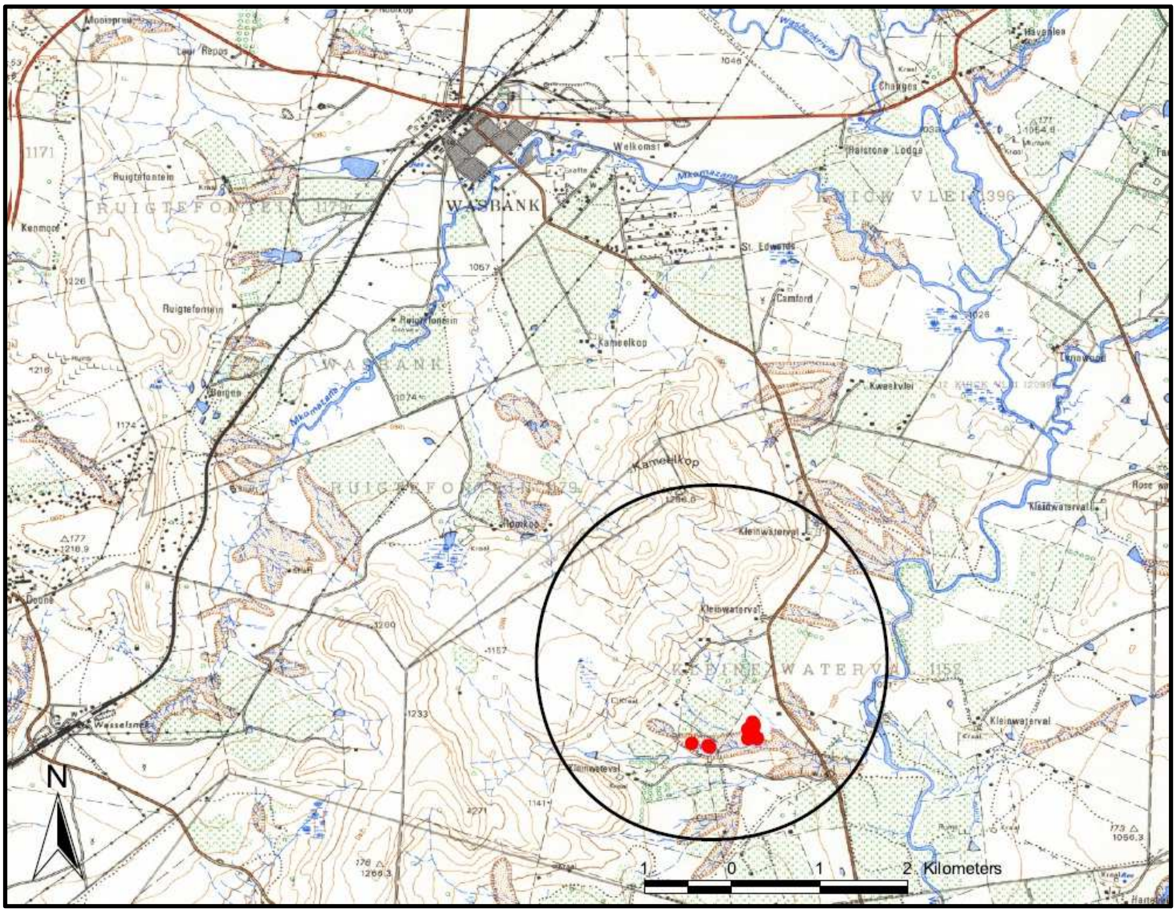


**Figure 4.10: Distribution points of *Cyrtanthus nutans* for the Wasbank area.**

Overall, the distribution of the sites of occurrence was fragmented, broken up by the various forms of land use. Sites of occurrence were predominantly along servitudes (rail and road), and on the periphery of agricultural camps and urban developments.

### 4.4.2 Topography - terrain unit, altitude and slope

The altitude range for the *Cyrtanthus nutans* plant distribution is at its lowest, 1 031 m (a.m.s.l.) in the Wasbank area and at its highest 1 459 m (a.m.s.l.) in the Rorke's Drift region (Table 4.2). The altitude range for all *Cyrtanthus nutans* plants were divided into 100 metre bands, ranging from 1 000-1 500 m (a.m.s.l.), inclusive of the minimum and maximum altitude readings for the sites of occurrence. The majority of plants (97.98%) occurred within the 1 100-1 300 m (a.m.s.l.) range, with fewer plants found in the higher lying areas such as Rorke's Drift. Plants in the Helpmekaar area were only found on the footslopes of the

Noustroop Pass. This indicates the possible influence of altitude on the abundance of the species (Figure 4.11).

**Table 4.2: Altitudes (a.m.s.l.) for the five main areas of distribution (extremes are highlighted)**

| Altitude range | CBD | DE | DNE | RD | WB |
|---|---|---|---|---|---|
| Mean | 1 242 | 1 159 | 1 227 | 1 205 | 1 037 |
| Minimum | 1 211 | 1 143 | 1 182 | 1 087 | **1 031** |
| Maximum | 1 291 | 1 243 | 1 265 | **1 459** | 1 047 |

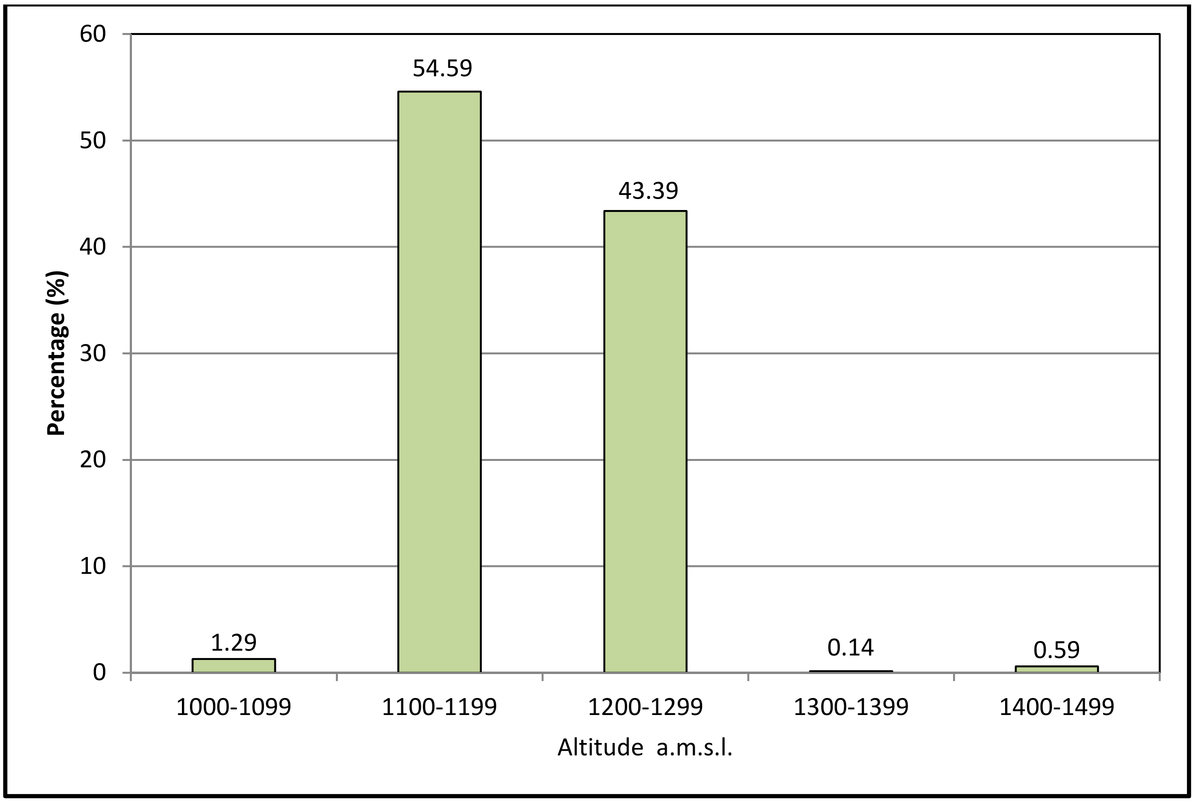


**Figure 4.11: Percentage of *Cyrtanthus nutans* plants per 100 m bands of altitude (a.m.s.l.) range.**

According to the terrain units, the majority of the sites (88%) were situated on the midslope (upper and lower) and only 11% were found on the footslope (Figure 4.12 and Table 4.3). McNeil (1967) reported that *Cyrtanthus* species can be found either in vleis or open grasslands. Scott-Shaw (1999) supported this statement and also stated that *Cyrtanthus nutans* can be found on the margins of vleis, which would be presented by a footslope rather than a midslope, as were the majority of populations found in this study. However the majority of these sites were situated in open grasslands. The majority of *Cyrtanthus nutans* populations (> 75%) were found on relatively level sites with gradients of less than 15°. In areas where uneven ground formed the basis of the topography, the *Cyrtanthus nutans* plants were found to occur on the more level areas.

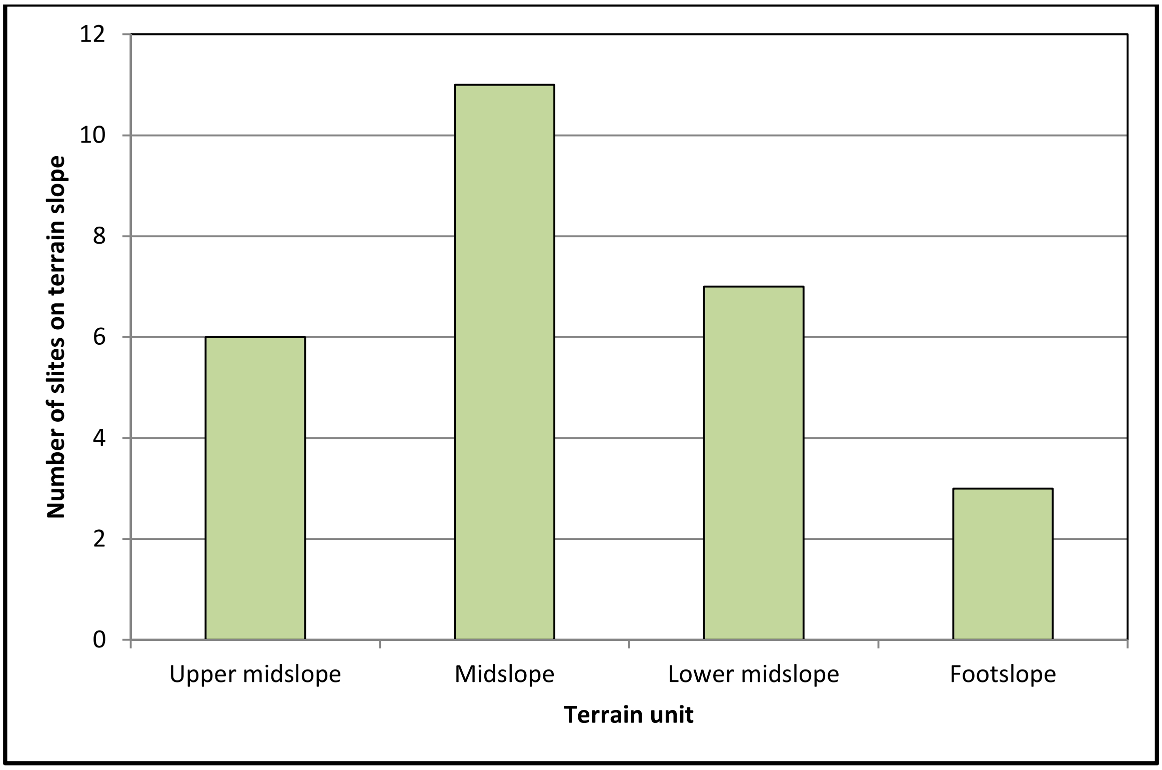


**Figure 4.12: Number of sites situated on terrain units.**

Overall, a pattern or similarity of the majority of the sites of occurrence was noticed. In terms of terrain, 70% of the plants were found on the mid to lower slopes of the landscape with estimated gradients of less than 10%. *Cyrtanthus nutans* had no preference for areas with a particular facing slope as the sites were relatively flat. The majority of the plants were found at an altitude range of between 1 100-1 300 m a.m.s.l.

**Table 4.3: Topography of sites**

| Main areas | Site names | Terrain unit | Mean altitude (m) a.m.s.l. | Mean slope (Percent %) |
|---|---|---|---|---|
| CBD | Aerodrome | Lower midslope | 1 292 | < 3 |
| | Dundee Junior School | Midslope | 1 239 | < 5 |
| | Meer | Midslope | 1 253 | < 5 |
| | Showgrounds | Midslope | 1 246 | < 5 |
| | RTI | Midslope | 1 252 | < 5 |
| | Smith Street | Lower midslope | 1 223 | < 5 |
| | Strathmore | Upper midslope | 1 269 | < 5 |
| DE | Consol | Footslope | 1 250 | < 3 |
| | Ingudlane Farm | Lower midslope | 1 236 | < 5 |
| | Ingudlane Reserve | Upper midslope | 1 256 | < 5 |
| | Lennox Railway | Midslope | 1 226 | 5-10 |
| | Lerryn Farm | Footslope | 1 218 | < 3 |
| | Peacevale | Lower midslope | 1 244 | < 8 |
| | Springfield | Lower midslope | 1 230 | < 5 |
| | Talana | Footslope | 1 213 | < 3 |
| DNE | Anton | Upper midslope | 1 208 | < 10 |
| | District Road | Midslope | 1 192 | < 5 |
| | Frik | Midslope | 1 210 | < 5 |
| | Malonjeni Station | Midslope | 1 170 | < 5 |
| | Triple C land | Upper midslope | 1 242 | < 10 |
| | Tayside | Lower midslope | 1 153 | < 5 |
| RD | Helpmekaar | Lower midslope | 1 222 | < 3 |
| | Muller | Upper midslope | 1 458 | < 8 |
| | Nquthu Road | Midslope | 1 187 | < 5 |
| | Nxala Road | Midslope | 1 123 | < 5 |
| | Rorke's Drift | Upper midslope | 1 177 | < 10 |
| WB | Kameelkop | Midslope | 1 036 | < 5 |

### 4.4.3 Population count

In total, 21 408 *Cyrtanthus nutans* flowering plants (excluding plants consisting of leaves only) were recorded over four spring seasons (2013-2016) in an area of approximately 1 450 $km^2$. The majority of flowering plants were recorded in the DNE (53%) and DE (25%) areas (Figure 4.13).

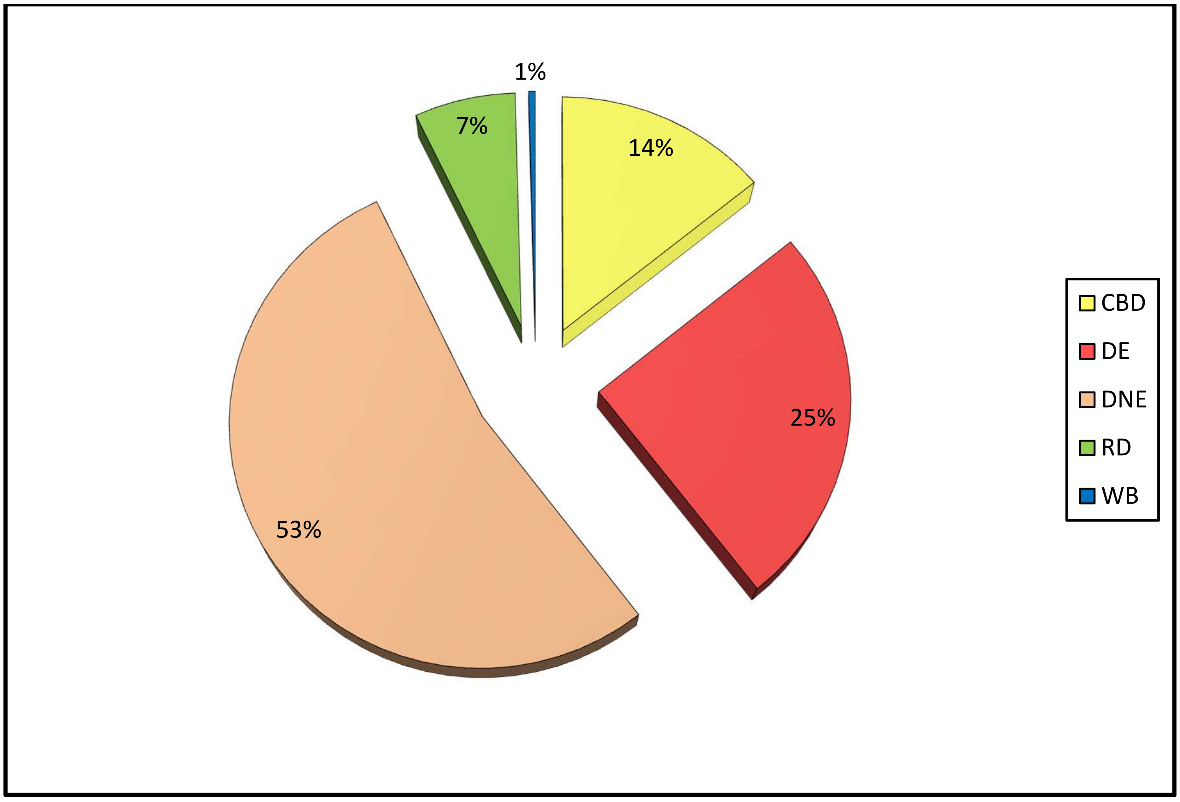


**Figure 4.13: Percentage of total number of *Cyrtanthus nutans* plants recorded for each of the five main areas.**

The majority of the flowering plants counted between 2013 and 2016 were recorded over the 2013 and 2014 seasons (81%), with fewer additional populations found during 2015 (14%) and 2016 (5%). This is possibly associated with the higher rainfall experienced in 2012/2013, subsequent seedling recruitment in the following season of 2014 and the lower rainfall in 2014/2015 (Table 4.4). As the current study progressed, the number of flowering plants counted each year declined. Taking plant characteristic limitations and the restriction of the length of the study period into account, there are most likely many small fragments of plants that went unrecorded in areas that were not traversed.

**Table 4.4: Plant population density for each site**

| Main areas | Site names | Total plant population counts | | | |
|---|---|---|---|---|---|
| | | Year | | | |
| | | 2013 | 2014 | 2015 | 2016 |
| CBD | Aerodrome | 1 702 | | | |
| | Dundee Junior School | 234 | | | |
| | Meer | 63 | | | |
| | Showgrounds | 700 | | | |
| | RTI | 24 | | | |
| | Smith Street | 239 | | | 52 |
| | Strathmore | 25 | | | |
| DE | Consol | 750 | | | |
| | Ingudlane Farm | | | 310 | |
| | Ingudlane Reserve | 52 | | | |
| | Lennox Railway | | 1 262 | | 49 |
| | Lerryn Farm | 293 | 91 | | 85 |
| | Peacevale | 12 | | | |
| | Springfield | 60 | | 2 164 | |
| | Talana | 300 | | | |
| DNE | Anton | | | 321 | |
| | District Road | | | 9 | |
| | Frik | | | 117 | |
| | Malonjeni Station | | 1 025 | | |
| | Triple C land | | 462 | | |
| | Tayside | 2 146 | 6 636 | | 700 |
| RD | Helpmekaar | 122 | 3 | | |
| | Muller | | | 111 | 15 |
| | Nquthu Road | | 954 | | |
| | Nxala Road | | 69 | | |
| | Rorke's Drift | 4 | 47 | | 108 |
| WB | Kameelkop | | 92 | | |
| | **Yearly Totals** | **6 726** | **10 641** | **3 032** | **1 009** |
| | **Total** | **21 408** | | | |

### 4.4.4 Presence/absence of fire

Burning of veld was a traditional method to reduce moribund material (Trollope, 1982). The majority of the sites had been burnt either in the current flowering season as part of the firebreak regime, or in the previous summer season to reduce moribund material for the grazing of livestock. In areas where no burning had taken place at the sites of occurrence, the grass sward was short or sparse. The following sites were recorded as having been burnt or unburnt for each of the main areas;

**CBD Sites**

Of the seven sites in the CBD area, only the Aerodrome had not been burnt. However grazing and resource use (thatch grass collection) throughout the year resulted in a relatively short veld (Table 4.5).

**Table 4.5: Presence or absence of fire in the CBD sites**

| Site identification | Fire presence winter/spring burn | |
|---|---|---|
| | Burnt | Unburnt |
| Aerodrome | | X |
| Dundee Junior School | X | |
| Meer | X | |
| Showgrounds | X | |
| RTI | X | |
| Smith Street | X | |
| Strathmore | X | |

**DE Sites**

The Consol and Ingudlane Farm sites had not been burnt in recent years, however the grass sward was relatively short due to cattle grazing. The Lerryn site was excluded from fire during the period of this study as a prevention measure against the experimental units being damaged by fire. The Talana site is burnt annually by the community for winter grazing of community cattle. The remainder of the sites were burnt as part of the firebreak regime by landowners and property owners (Table 4.6).

**Table 4.6: Presence or absence of fire in the DE sites**

| Site identification | Fire presence winter/spring burn | |
|---|---|---|
| | Burnt | Unburnt |
| Consol | | X |
| Ingudlane Farm | | X |
| Ingudlane Reserve | X | |
| Lennox Rail | X | |
| Lerryn Farm | | X |
| Peacevale | X | |
| Springfield | X | |
| Talana | X | |

**DNE Sites**

The Tayside site had a mixture of both burnt (in the road and railway servitudes) and unburnt areas (camps had not been burnt for a number of years as part of the management decision to rest the camps). The Malonjeni site, serving as the servitude between the road or railway lines and the cattle grazing camps were burnt as firebreaks by the landowners. The remainder of the sites had a short grass sward due to cattle grazing (Table 4.7).

**Table 4.7: Presence or absence of fire in the DNE sites**

| Site identification | Fire presence winter/spring burn | |
|---|---|---|
| | Burnt | Unburnt |
| Anton | | X |
| District Road | | X |
| Tayside | XX | XX |
| Frik | | X |
| Malonjeni Station | XX | XX |

XX Mixed burnt and unburnt

**RD Sites**

The majority of the sites were along road and railway servitudes and burnt, except the Muller site, which was utilised as a grazing camp and the Nquthu Road which was predominantly burnt except a section that fell within the outer perimeter of the Sunshine Farm which was not burnt but was heavily grazed (Table 4.8)

**Table 4.8: Presence or absence of fire in the RD sites**

| Site identification | Fire presence winter/spring burn | |
|---|---|---|
| | Burnt | Unburnt |
| Helpmekaar | X | |
| Muller | | X |
| Nquthu Road | XX | XX |
| Nxala Road | X | |
| Rorke's Drift Road | X | |

XX Mixed burnt and unburnt

**WB Site**

Hot, uncontrolled fires took place on the property during 2013 and 2014. A decision was made by management staff not to burn any areas except firebreaks during 2015 (Table 4.9).

**Table 4.9: Presence or absence of fire in the WB site**

| Site identification | Fire presence winter/spring burn | |
|---|---|---|
| | Burnt | Unburnt |
| Kameelkop | | X |

Overall, the majority of the sites of occurrence had been burnt and if not burnt had a short grass sward, indicating a preference of emerging *Cyrtanthus nutans* plants for areas where less competition from other species occurred. Gordon-Gray and Wright, (1969) supported this by stating that fire is an important tool to remove moribund grass. Dyer, (1954) reported that *Cyrtanthus nutans* is tolerant to fire and Craib (2004) found that fires from May to early July provide the best conditions with the dense grass cover removed.

### 4.4.5 Land use

Human activity in the form of pedestrian thoroughfares, informal vehicle tracks or mountain bike trails were found at a few of the sites. Agricultural practices in the form of livestock grazing and crop production were the main farming activities.

**CBD Sites**

Four of the seven sites had some form of human activities. The Meer site was the only site that had no cattle grazing or human activity, as it is privately owned land that is fully fenced. The neighbouring property to this is grazed throughout the year and no flowers were observed beyond the boundary fence (Table 4.10).

**Table 4.10: Activities in the CBD sites**

| Site identification | Human related activity | | Agriculture | |
|---|---|---|---|---|
| | Yes | No | Grazed/mown | Ungrazed |
| Aerodrome | X | | X | |
| Dundee Junior School | X | | X | |
| Meer | | X | | X |
| Showgrounds | X | | X | |
| RTI | | X | X | |
| Smith Street | X | | X | |
| Strathmore | | X | X | |

**DE Sites**

Only Talana of the DE sites had relatively high human activity such as informal vehicle tracks and high pedestrian activity coupled with high levels of cattle grazing. The remaining sites had low human activity with minimal grazing. No large herbivore grazing was observed at the Peacevale or Lennox railway sites during the study period (Table 4.11).

**Table 4.11: Activities in the DE sites**

| Site identification | Human related activity | | Agriculture | |
|---|---|---|---|---|
| | Yes | No | Grazed/mown | Ungrazed |
| Consol | | X | X | |
| Ingudlane Farm | | X | X | |
| Ingudlane Reserve | | X | X | |
| Lennox Railway | | X | | X |
| Lerryn Farm | | X | X | |
| Peacevale | | X | | X |
| Springfield | | X | X | |
| Talana | X | | X | |

**DNE Sites**

In the Dundee North-East area, the human activity within the actual sites was almost non-existent as sites were found in and around fenced cattle camps or along road and railway servitudes. Sites that were not within fenced camps were generally not grazed as cattle had no access to areas outside the camps, however the Tayside site was either minimally grazed (some camps had been allowed to rest) or ungrazed (along the road and railway servitudes) (Table 4.12)

**Table 4.12: Activities in the DNE sites**

| Site identification | Human related activity | | Agriculture | |
|---|---|---|---|---|
| | Yes | No | Grazed/mown | Ungrazed |
| Anton | | X | X | |
| District Road | | X | | X |
| Tayside | | X | XX | XX |
| Frik | | X | | X |
| Malonjeni Station | | X | XX | XX |

**XX** Mixed grazed and ungrazed

**RD Sites**

Sites within the Rorke's Drift area had almost no evidence of human activity. All sites were ungrazed except portions of the Nquthu Road site which included portions of the Sunshine Farm which had been grazed. The Muller site had also been grazed as this was utilised as a grazing camp (Table 4.13).

**Table 4.13: Activities in the RD sites**

| Site identification | Human related activity | | Agriculture | |
|---|---|---|---|---|
| | Yes | No | Grazed/mown | Ungrazed |
| Helpmekaar | | X | | X |
| Muller | | X | X | |
| Nquthu Road | | X | XX | XX |
| Nxala Road | | X | | X |
| Rorke's Drift Road | | X | | X |

**XX** Mixed grazed and ungrazed

**WB Sites**

The Kameelkop site in the Wasbank area was historically a highly eroded area that is now in a recovery stage. Low grazing pressure from antelope and cattle was observed. Minimal human activities were observed (Table 4.14).

**Table 4.14: Activities in the WB site**

| Site identification | Human related activity | | Agriculture | |
|---|---|---|---|---|
| | Yes | No | Grazed/mown | Ungrazed |
| Kameelkop | | X | X | |

Overall, the majority of the sites had minimal to zero human activity, only sites in the vicinity of Dundee town were impacted by activities of a negative human nature. *Cyrtanthus nutans* had a preference for areas that were burnt or had a short or sparse grass sward, allowing for a reduction in competition from other species.

Craib (2004) noted that changes to the habitat of *Cyrtanthus galpinii* had occurred only after 20 years of studying the plant with open woodland being cut for firewood when landuse changed from cattle grazing to sheep and goat grazing. Grazing pressure had also increased and plants located near seepage lines were now becoming trampled. Plants situated on the rocky outcrops where available grazing occurred were not disturbed.

### 4.4.6 Herbivores

Large to medium livestock such as cattle, horses and goats, grazed at the majority of the sites. Grazing levels ranged between light grazing, particularly in the spring months after the first spring rains, to heavy/moderate grazing on communal land such as at the Talana and Consol sites. Other *Cyrtanthus nutans* sites are located on road and railway servitudes between fenced pastures belonging to private landowners. Large livestock also had no access to these areas. Other herbivores that occur in the area include Grey Duiker (*Sylvicapra grimmia*), Common Reedbuck (*Redunca arundinum*), Porcupine (*Hystrix africaeaustralis*), Bushpig (*Potamochoerus larvatus*), Warthog (*Phacochoerus africanus*) and Scrub hare (*Lepus saxatilis*). Invertebrate species such as grasshoppers, earthworms and ants were also observed during surveys (Figure 4.14).

Both invertebrates and vertebrates equally affect the growth rates of a plant population. When taking domestic stock herbicides and pesticides out of the equation, floral and seed herbivorous species have an equal effect on the growth of plant populations (Maron and Crone, 2006).

### 4.4.7 Negating factors

During the period of data collection, a number of man-induced actions were observed, that could have resulted in the loss of *Cyrtanthus nutans* plants. The grading of road servitudes by the KZN Department of Transport, carried out for enhanced vehicular and pedestrian visibility and rainwater runoff, was observed on a number of occasions (Figure 4.15). Damage to plants was possibly only seasonal, with the chance that the same plant might emerge the following season if the bulb had not been damaged (Figure 4.16). Vehicle movement on informal routes in the veld as well as along the road servitudes was also a source of possible damage to plant populations.

McMaster (2009) stated that the picking of flowers at the roadside is a serious crime in terms of the provinical Ordinances, however destruction by road maintenance crew is overlooked, as was the case with the N9 road between Biervlei Dam and Aberdeen in the Eastern Cape, South Africa where the entire verge of the road servitude had been cut to less than 10cm above the ground from fence to fence. Severely damaged plants were battling to flower and stay alive.

Long term pedestrian traffic is considered to possibly be damaging to plant populations, causing compaction of soil and the possible reduction in seed germination, seedling emergence and root development (Figure 4.17). Illegal dumping of building materials and garden refuse could also have restricted the expansion of micro-populations due to the change in habitat (Figure 4.18).

Herbivore damage prior to flowers reaching the seed dispersal stage probably affected the population particularly in drought years when there was limited vegetation available for foraging. Herbivory by rodents, insects and mammals was a common occurrence. Disturbance to bulbs micro-habitat by herbivores, in search of plant material, was also identified as a threat to plant populations (Figure 4.19).

McMaster (2009) stated that plants that are constantly defoliated have the inability to flower and set seed and that many species that are not generally inconspicuous will be severely affected and it will go unnoticed.

**Figure 4.14: Grasshopper activity amongst *Cyrtanthus nutans* flowers.**

**Figure 4.15: Department of Transport grader clearing road servitudes where *Cyrtanthus nutans* plants occur.**

**Figure 4.16: *Cyrtanthus nutans* plant flattened by a grader tyre.**

**Figure 4.17: Damage to plants through pedestrian thoroughfares.**

**Figure 4.18: Illegal dumping in *Cyrtanthus nutans* habitat.**

**Figure 4.19: Damage to plants by herbivores.**

Human activities that have a negative influence on *Cyrtanthus nutans* can be reduced when correct management practices are set in place. In addition, large and medium livestock appeared to have the ability to reduce *Cyrtanthus nutans* populations during a single grazing period in a camp by dramatically reducing the recruitment of seedlings.

### 4.4.8 Geology and soils

Gradients play a fundamental role in water drainage and the subsequent formation of soils and nutrient deposits within the landscape. The soil fertility environment of the plant is not currently known, however the robustness of the plant population provides a good indication of whether the site is favourable to the species. Soil acidity levels, clay percentages and nutrient levels based on the soil sample readings, provide an indication of a favourable soil environment (Gordon, 2017: Personal Communication).

#### 4.4.8.1 Soil analysis

Eight sites showing significant populations of *Cyrtanthus nutans* were selected for the soil samples (Figure 4.20) and varied in topography, land-use and altitude. The dominant parent rock at the sites was dolerite, with only two sites underlain with shale. Various soil forms were found amongst the eight sites. The intrinsic soil texture and clay percentage at each sample site typically reflected the geology for the area (Table 4.15).

**Chemical Characteristics**

**Nitrogen (N)**

Nitrogen, an essential nutrient and key catalyst for photosynthesis in plants, was within acceptable levels at all sites (between 0.1 and 0.22%) except for the Tayside site where levels were low for the topsoil (Sample A - 0.09%) and non-existent (0.0%) for the subsoil (Sample B) owing to the low organic carbon percentage levels. Nitrogen levels for the Showground and Talana sites were considered good ($\geq$ 0.2%), particularly for the north-western region of KZN (Table 4.16).

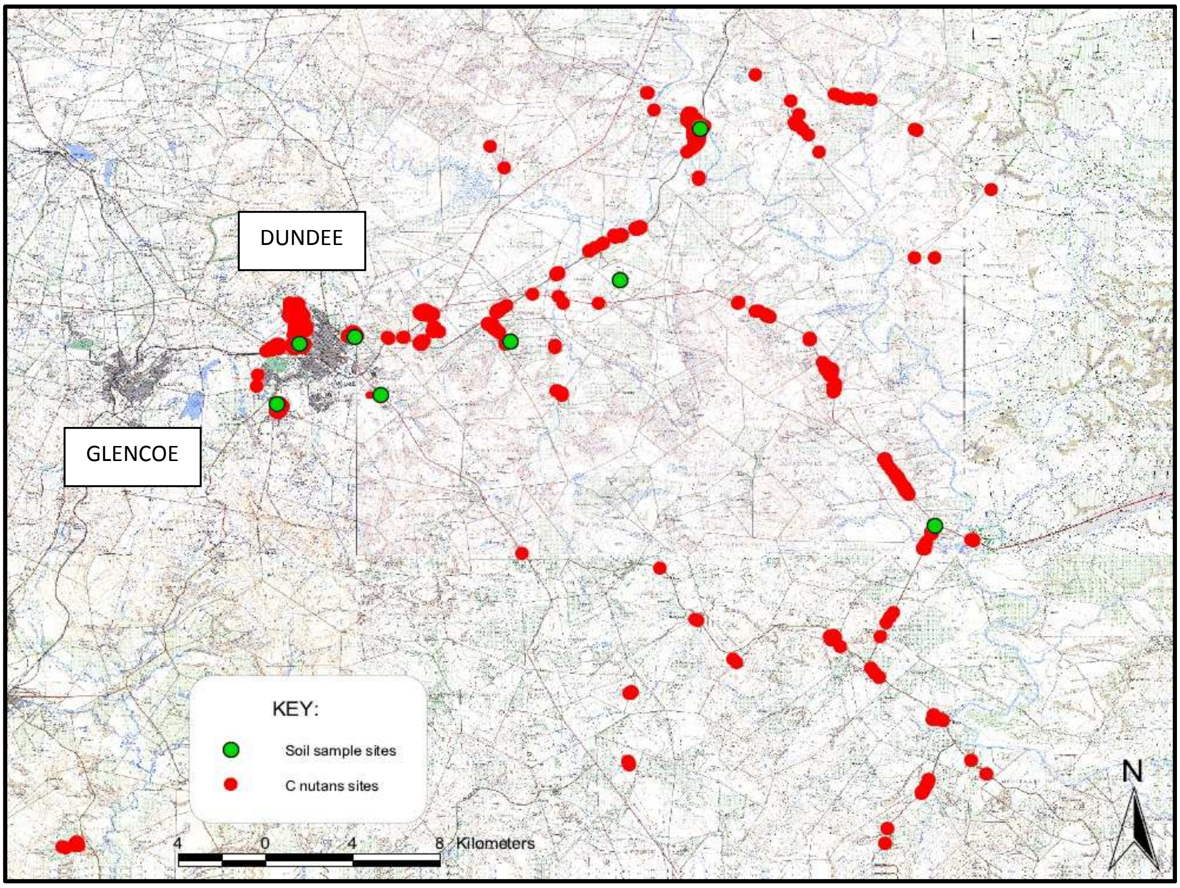


**Figure 4.20: Soil sampling sites in the *Cyrtanthus nutans* distribution area.**

**Table 4.15: Soil sampling sites within the five main areas**

| Area | Site name | Soil form | Parent material |
|---|---|---|---|
| CBD | Aerodrome | Avalon | Dolerite/Shale |
| | Showgrounds | Hutton | Dolerite |
| DE | Consol | Avalon | Shale |
| | Lerryn Farm | Katspruit | Dolerite |
| | Talana | Rensburg | Dolerite |
| DNE | Tayside | Arcadia | Dolerite |
| | Triple C land | Longlands | Dolerite/Sandstone |
| RD | Nquthu Road | Glenrosa | Sandstone |

**Phosphorus (P)**

Phosphorus levels were low (range of five to seven for the topsoil Sample A and three to five for the subsoil Sample B) when compared to an agricultural perspective, where 12 mg $L^{-1}$ is the minimum amount required for maize on soils with a sample density < 1.00 mg $L^{-1}$ (Manson *et al*. 2012). Phosphorus levels tend to be low in virgin sites due to minerals in the parent material being low in phosphorus. One can therefore surmise that low phosphorus levels are adequate for *Cyrtanthus nutans* plants (Table 4.16).

**Potassium (K)**

Exchangeable potassium levels were moderate to high at all the sites, with a range of between 92 and 228 for the topsoil (Sample A) and 36 to 133 for the subsoil (Sample B), possibly due to the inherent geology of the area. In terms of an agricultural maize norm, 120 mg $L^{-1}$ is acceptable for soils with a sample density of $\leq$ 1.35 mg $L^{-1}$ (Soil Classification Working Group, 1991). The robustness of the plant could suffer with low potassium levels however *Cyrtanthus nutans* may not require as much potassium as agricultural crops or is possibly able to extract potassium efficiently (Table 4.16).

**Table 4.16: Nitrogen, Phosphorus and Potassium levels at the eight soil sample sites**

| Site name | Nitrogen N (%) | | Phosphorus P (mg $L^{-1}$) | | Potassium K (mg $L^{-1}$) | |
|---|---|---|---|---|---|---|
| | Sample | | Sample | | Sample | |
| | A | B | A | B | A | B |
| Aerodrome | 0.19 | 0.10 | 7 | 5 | 100 | 55 |
| Showgrounds | 0.20 | 0.15 | 6 | 5 | 92 | 36 |
| Talana | 0.21 | 0.12 | 5 | 3 | 164 | 118 |
| Lerryn Farm | 0.16 | 0.11 | 7 | 5 | 168 | 120 |
| Consol | 0.19 | 0.12 | 5 | 4 | 228 | 133 |
| Tayside | 0.09 | 0.00 | 5 | 5 | 136 | 113 |
| Triple C land | 0.16 | 0.05 | 7 | 5 | 172 | 109 |
| Nquthu Road 2 | 0.10 | 0.03 | 7 | 5 | 172 | 133 |
| **Mean** | **0.16** | **0.08** | **6** | **5** | **154** | **102** |
| **Range** | **0.1-0.22** | **0-0.15** | **5-7** | **3-5** | **92-228** | **36-133** |

A - Topsoil and B - Subsoil

**Calcium and Magnesium**

In an ideal situation, based on agricultural requirements, a ratio of 4:1 for calcium : magnesium is necessary (Manson *et al*. 2012). High magnesium levels can lead to imbalances in nutrient uptake of potassium as an example. Physically, soil crusting occurs with high magnesium, therefore hampering effective rainfall penetration (Gordon, 2017: Personal Communication).

Calcium and magnesium levels at the Talana and Tayside sites were found to be high in relation to the others, contributing to their high total cations. Calcium and magnesium levels for the remaining sites varied from low at the Triple C land and Vants Drift (Nquthu Road 2) resulting in dystrophic (< 5 cmol $L^{-1}$) through to mesotrophic soils (5 - 15 cmol $L^{-1}$) at the Consol site, Aerodrome, Showgrounds and Lerryn Farm accompanied by moderate leaching (Table 4.17).

**Table 4.17: Calcium, magnesium and total cations at the eight soil sample sites**

| Site name | Calcium Ca (mg $L^{-1}$) | | Magnesium Mg (mg $L^{-1}$) | | Total Cations (cmol $L^{-1}$) | |
|---|---|---|---|---|---|---|
| | Sample | | Sample | | Sample | |
| | A | B | A | B | A | B |
| Aerodrome | 642 | 553 | 278 | 284 | 5.97 | 5.34 |
| Showgrounds | 745 | 757 | 249 | 259 | 6.43 | 6.39 |
| Talana | 1 625 | 1 901 | 836 | 1 106 | 15.46 | 18.93 |
| Lerryn Farm | 803 | 765 | 568 | 1 043 | 9.19 | 12.80 |
| Consol | 539 | 488 | 185 | 274 | 5.13 | 5.05 |
| Tayside | 1 919 | 2 738 | 1 496 | 1 867 | 22.31 | 29.38 |
| Triple C land | 303 | 175 | 102 | 71 | 2.88 | 1.92 |
| Nquthu Road 2 | 355 | 245 | 136 | 115 | 3.47 | 2.79 |
| **Mean** | **866** | **953** | **481** | **627** | **8.86** | **10.33** |
| **Range** | **303-1 919** | **175-2 738** | **102-1 496** | **71-1 867** | **2.88-22.31** | **1.92-29.38** |

A - Topsoil and B - Subsoil

### Acidity

Low acid saturation levels (< 10%) due to the presence of calcium and magnesium resulted throughout the sites. Soil pH (KCl) levels at all of the sites ranged from 4.0 to 5.8 in both the topsoil (Sample A) and subsoil (Sample B) (Table 4.18).

**Table 4.18: Acidity and pH levels at soil sampled sites**

| Site name | Acid saturation (%) | | pH (KCl) | |
|---|---|---|---|---|
| | Sample | | Sample | |
| | A | B | A | B |
| Aerodrome | 4 | 2 | 4.5 | 5.0 |
| Showgrounds | 7 | 6 | 4.1 | 4.3 |
| Talana | 0 | 0 | 4.5 | 5.0 |
| Lerryn Farm | 1 | 1 | 5.2 | 5.8 |
| Consol | 6 | 0 | 4.1 | 5.2 |
| Tayside | 0 | 0 | 5.1 | 5.3 |
| Triple C land | 3 | 9 | 4.6 | 4.2 |
| Nquthu Road 2 | 4 | 10 | 4.3 | 4.0 |
| **Mean** | **3.1** | **3.5** | **4.5** | **4.9** |
| **Range** | **0 7** | **0-10** | **4.1-5.2** | **4.0-5.8** |

A - Topsoil and B - Subsoil

### Clay

Clay percentages vary throughout the sites with values ranging between 15 and 50%. The Showgrounds site in particular indicated a 50% clay composition, located on a midslope position with good drainage. The site lies upon dolerite geology with high traces of hematite iron oxides in the soil, which impart the red colour. The Triple C land site had the lowest clay percentage of all sites. Underlain by medium to coarse-grained sandstone, this old agricultural land’s mineralogy consists mainly of kaolinite and subdominant illite, similar to the Dundee Agricultural Research Station (DARS) (Gordon, 2017: Personal communication) and is represented by a loamy textured soil. All other sites clay percentages ranged between 20 and 40% (Table 4.19).

**Organic Carbon**

Organic carbon percentage levels were acceptable in both A and B samples at the sites such as the Showgrounds, where no form of land modification has ever occurred, and the Aerodrome and Consol sites where the land has remained undisturbed for a long period of time. Talana also has one of the highest organic carbon percentages. All four sites however, are utilised regularly for cattle grazing, and the inclusion of cattle manure and the slope position contribute to the soil's composition was a probable cause for higher organic carbon levels. At the Lerryn and Tayside sites, no cattle grazing occurred and at the Nquthu Road site at Vants Drift (Nquthu Road 2), the hygrophilous grasslands near the Buffalo River's banks were favoured more by the cattle than the higher lying areas where samples were taken. The Triple C land is evidently a transformed land that has lain dormant for many years, but has recovered well and is currently utilised for cattle grazing (Table 4.19).

**Table 4.19: Clay and organic carbon percentages at the soil sample sites**

| Site name | Clay (%) | | Organic Carbon (%) | |
|---|---|---|---|---|
| | Sample | | Sample | |
| | A | B | A | B |
| Aerodrome | 22.0 | 22.5 | 2.05 | 0.87 |
| Showgrounds | 50.0 | 52.5 | 2.86 | 2.37 |
| Talana | 29.5 | 35.5 | 2.63 | 1.60 |
| Lerryn Farm | 20.5 | 25.5 | 1.68 | 0.95 |
| Consol | 28.5 | 27.5 | 2.21 | 0.73 |
| Tayside | 34.5 | 39.0 | 1.77 | 0.96 |
| Triple C land | 15.0 | 9.0 | 1.78 | 0.08 |
| Nquthu Road 2 | 18.5 | 21.5 | 0.90 | 0.52 |
| **Mean** | **27.3** | **29.1** | **1.98** | **1.01** |
| **Range** | **15-34.5** | **9-52.5** | **0.9-2.86** | **0.52-2.365** |

A - Topsoil and B - Subsoil

**Zinc**

Overall, zinc levels were low, where the norm for maize production is 1.5 mg $L^{-1}$ (Manson *et al.* 2012). Levels recorded for the Lerryn site was the lowest of all the sites (0.5 and 0.3 mg $L^{-1}$ for A & B samples respectively. The highest in the A sample was for the Aerodrome at 3.8 mg $L^{-1}$. However, *Cyrtanthus nutans* may be resilient to low zinc levels as no indication of stunted growth due to low zinc levels was noticed throughout any of the sites.

**Overview**

*Cyrtanthus nutans* plants were mainly found in areas where parent rock was dolerite. Soil samples from sites that were significantly populated with *Cyrtanthus nutans* indicated moderate nitrogen percentages of > 0.16%. Preferred areas are undisturbed with high organic carbon percentages (> 1.8%). *Cyrtanthus nutans* also appeared to prefer soils with low acidity (< 10 acid saturation %) and is tolerant of a relatively wide range of textures (15 to 50 % clay).

*Cyrtanthus macmasteri*, a species found near the Kei River in the Eastern Cape, South Africa also occurs in areas that arise out of sedimentary rocks of fine sandstone yet extending into areas where soils are formed from weathered dolerite intrusions (McMaster, 2004)

### 4.4.9 Vegetation

Vegetation assessment sites were selected primarily for their occurrence of known populations of *Cyrtanthus nutans*, and secondly for the land use type and variation in vegetation composition (Figure 4.21). Sites occurred within three BRG, namely Dry Highland Sourveld (BRG 9), Moist Tall Grassveld (BRG 12) and Sour Sandveld (BRG 14) (Figure 4.22).

In this current study veld condition (as a percentage) is measured against the benchmark of its corresponding BRG (Table 4.20). Of the 17 sites assessed, only the Meer site scored 100%. Comprising of more than 70% Decreaser species and almost 20% Increaser I species, this site was clearly not utilised for grazing and infrequently burnt. Another site that was in good condition was the Aerodrome, scoring 84%, with a high percentage of Increaser I (44.7%) and Decreaser (17%) species. This site is mown annually for the Dundee July horse race and was grazed throughout the year by a small herd of cattle. This site had a substantial population of flowers. The majority of the remaining sites scored a rating of between 34 and 66% in comparison to the benchmark of the corresponding BRG. The grass species were Increaser IIb and IIc, indicating the high grazing pressure these sites are under (Table 4.20).

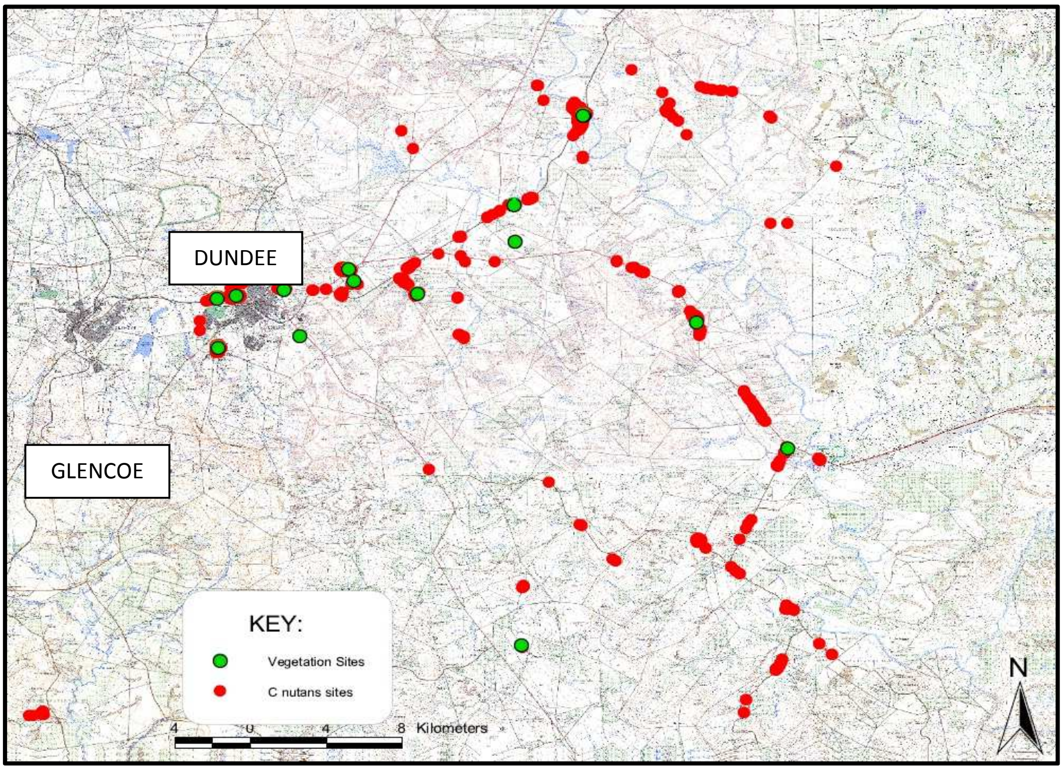


**Figure 4.21: Vegetation assessment sites in the distribution study area.**

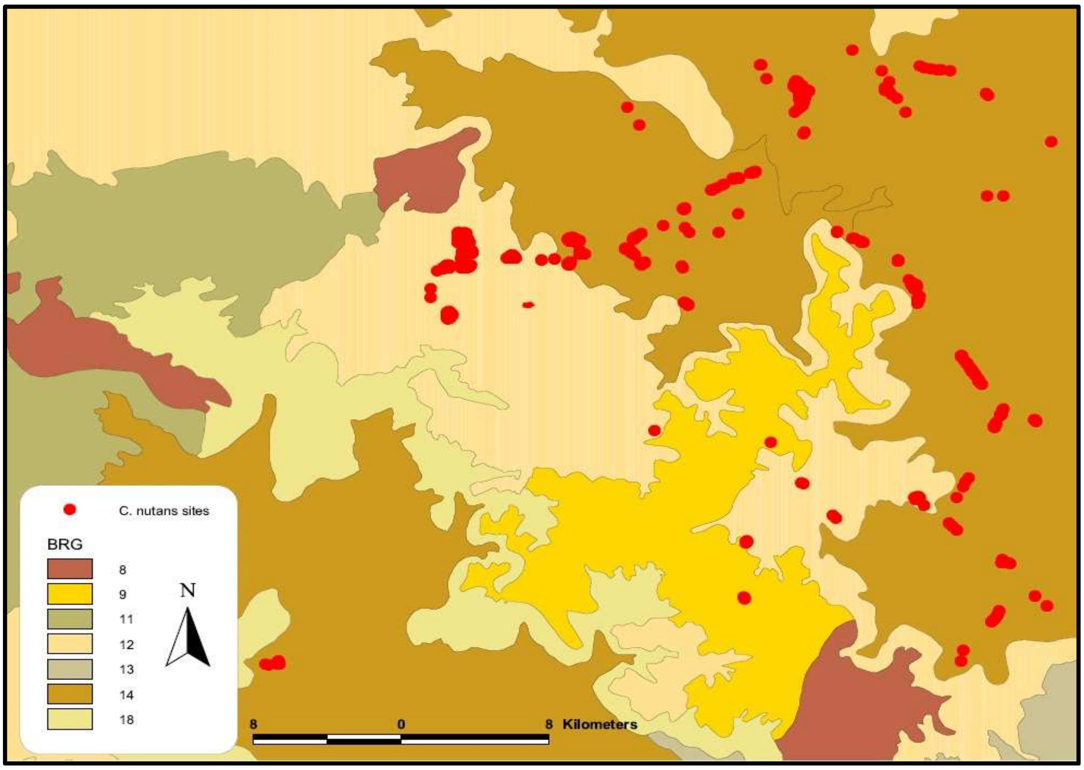


**Figure 4.22: *Cyrtanthus nutans* sites located within the Bioresource Groups.**

Two sites which rated low in comparison to the Benchmark system were the Talana (31%) and Lerryn (22%) sites. The Talana site has been utilised as a communal grazing area for many years; grazing pressure is high and the site is burnt annually. Almost 80% of the species on this site are from the Increaser IIb and IIc group. The Lerryn site has for the past few years been excluded from grazing. Cattle are not allowed access to the site and the only herbivores present in the area are a small group of Common Reedbuck (*Redunca arundinum)* and an occasional Grey Duiker (*Sylvicapra grimmia*). However the high historical grazing pressure before the site was fenced off is evident. Increaser III species dominate the site, a sign of selective overgrazing (Table 4.21).

**Table 4.20: Veld condition assessments relative to benchmark sites**

| **Area** | **Site name** | **Total number of plants for site** | **Bioresource Group** | **Veld condition (%)** |
|---|---|---|---|---|
| CBD | Aerodrome | 1 702 | Moist Tall Grassveld | 84 |
| | Meer | 63 | Moist Tall Grassveld | 100 |
| | Showgrounds | 700 | Moist Tall Grassveld | 40 |
| | Smith Street | 291 | Moist Tall Grassveld | 63 |
| DE | Consol | 750 | Moist Tall Grassveld | 48 |
| | Lerryn Farm | 469 | Sour Sandveld | 22 |
| | Ingudlane Farm | 310 | Sour Sandveld | 40 |
| | Springfield | 2 224 | Sour Sandveld | 60 |
| | Talana | 300 | Moist Tall Grassveld | 31 |
| DNE | Tayside 1 | 9 482 | Sour Sandveld | 62 |
| | Tayside 2 | | Sour Sandveld | 56 |
| | Malonjeni 1 | 1 025 | Sour Sandveld | 49 |
| | Malonjeni 2 | | Sour Sandveld | 46 |
| | Triple C land | 462 | Sour Sandveld | 40 |
| RD | Nquthu Road 1 | 954 | Sour Sandveld | 54 |
| | Nquthu Road 2 | | Sour Sandveld | 44 |
| | Muller | 126 | Dry Highland Sourveld | 63 |

**Table 4.21: Ecological status score of the vegetation assessment sites**

<table>
<tr><th>Site name</th><th>Increaser 1</th><th>Benchmark value</th><th>Decreaser</th><th>Benchmark value</th><th>Increaser II a</th><th>Benchmark value</th><th>Increaser II b</th><th>Benchmark value</th><th>Increaser II c</th><th>Benchmark value</th><th>Increaser III</th><th>Benchmark value</th></tr>
<tr><td colspan="13">Dry Highland Sourveld (BRG 9)</td></tr>
<tr><td>Muller</td><td>8.0</td><td>23</td><td>24.0</td><td>52</td><td>20.0</td><td>7</td><td>42.0</td><td>5</td><td>6.0</td><td>7</td><td>0.0</td><td>6</td></tr>
<tr><td colspan="13">Moist Tall Grassveld (BRG 12)</td></tr>
<tr><td>Lerryn</td><td>25.9</td><td rowspan="8">19</td><td>0.0</td><td rowspan="8">53</td><td>11.1</td><td rowspan="8">9</td><td>9.3</td><td rowspan="8">11</td><td>0.0</td><td rowspan="8">8</td><td>53.7</td><td rowspan="8">0</td></tr>
<tr><td>Malonjeni 1</td><td>0.0</td><td>5.9</td><td>23.5</td><td>31.4</td><td>9.8</td><td>29.4</td></tr>
<tr><td>Malonjeni 2</td><td>0.0</td><td>0.0</td><td>0.0</td><td>14.3</td><td>79.6</td><td>6.1</td></tr>
<tr><td>Triple C land</td><td>0.0</td><td>0.0</td><td>0.0</td><td>16.0</td><td>80.0</td><td>4.0</td></tr>
<tr><td>Tayside 1</td><td>21.8</td><td>29.1</td><td>0.0</td><td>7.3</td><td>41.8</td><td>0.0</td></tr>
<tr><td>Tayside 2</td><td>0.0</td><td>26.3</td><td>0.0</td><td>22.8</td><td>50.9</td><td>0.0</td></tr>
<tr><td>Springfield</td><td>14.9</td><td>29.8</td><td>4.3</td><td>27.7</td><td>4.3</td><td>19.1</td></tr>
<tr><td>Ingudlane</td><td>11.1</td><td>0.0</td><td>0.0</td><td>61.1</td><td>17.8</td><td>1.9</td></tr>
<tr><td colspan="13">Sour Sandveld (BRG 14)</td></tr>
<tr><td>Nquthu Road 1</td><td>2.0</td><td rowspan="8">45</td><td>20.0</td><td rowspan="8">28</td><td>0.0</td><td rowspan="8">7</td><td>42.0</td><td rowspan="8">12</td><td>26.0</td><td rowspan="8">5</td><td>10.0</td><td rowspan="8">3</td></tr>
<tr><td>Nquthu Road 2</td><td>5.8</td><td>0.0</td><td>3.8</td><td>34.6</td><td>38.8</td><td>0.0</td></tr>
<tr><td>Talana</td><td>4.0</td><td>14.0</td><td>4.0</td><td>46.0</td><td>32.0</td><td>0.0</td></tr>
<tr><td>Aerodrome</td><td>44.7</td><td>17.0</td><td>6.4</td><td>17.0</td><td>6.4</td><td>8.5</td></tr>
<tr><td>Showgrounds</td><td>3.8</td><td>3.8</td><td>0.0</td><td>48.1</td><td>42.3</td><td>1.9</td></tr>
<tr><td>Meer</td><td>19.6</td><td>70.6</td><td>2.0</td><td>5.9</td><td>0.0</td><td>2.0</td></tr>
<tr><td>Smith street</td><td>37.3</td><td>33.3</td><td>3.9</td><td>13.7</td><td>7.8</td><td>3.9</td></tr>
<tr><td>Consol</td><td>6.0</td><td>14.0</td><td>10.0</td><td>26.0</td><td>40.0</td><td>4.0</td></tr>
</table>

Benchmark values in bold are for the sites of each Bioresource Groups

## 4.5 CONCLUSION

The fragmented populations of *Cyrtanthus* nutans, found predominantly along servitudes and on the periphery of agricultural land and urban developments occurred predominantly on the mid and footslopes of relatively flat terrain within a narrow altitude range of between 1 100 and 1 300 m a.m.s.l., mainly in the east and north-eastern areas of Dundee. Climatic influence plays a major role in the stability of the population, with fluctuating changes in rainfall and temperature during drought years reducing seedling recruitment for future populations.

*Cyrtanthus nutans* occurs predominantly in the Moist Tall Grassveld and Sour Sandveld BRG (BRG 12 and BRG 14 respectively) in veld where Decreaser species are present. However *Cyrtanthus nutans* has a preference for sites where grass swards are short or burnt with little herbaceous competition, and with minimal herbivorous activity and occurs at undisturbed sites of a wide variety of textured soils, high in organic carbon, with moderate nitrogen levels and low in acidity.

Little is neither known about how plant-plant competition influences plant abundance (Howard and Goldberg, 2001) nor its importance relative to other abiotic or biotic factors (Maron and Crone, 2006)

# CHAPTER 5

# THE INFLUENCE OF CLIMATOLOGY, FIRE AND DEFOLIATION ON THE EMERGENCE AND SURVIVAL OF *Cyrtanthus nutans*

## 5.1 INTRODUCTION

The influence of ecological factors and management practices on the emergence, seedling recruitment and survival of *Cyrtanthus nutans* was investigated. The emergence of *Cyrtanthus nutans* plants was thought to be directly associated with changes in climatological factors. However fire and defoliation can also play a possible role in the emergence of these plants. Fire and defoliation as management practices could have beneficial or detrimental effects on floral populations if incorrectly implemented (Huggett, 2004; Maron and Crone, 2006).

The burning of grassland plays a vital role in the maintenance of bulbous plants and succulents in the summer rainfall central and eastern interior of South Africa (Craib, 2004). As validated by (Le Maitre and Brown, 1992), the environmental cues for fire lily flowering are unknown. Potential cues include direct fire that produces intense heat shock or chemicals from smoke and charred wood and indirect effects of fire are the increased nutrients and elevated soil temperatures in sites where burning took place.

## 5.2 AIM

The aim of this study, in achieving the research objective, was to determine the effect of climatology, fire and defoliation on the emergence, seedling recruitment and survival of *Cyrtanthus nutans* in north-western KZN and to carry out the following:

- Analyse the climatological data and its influence on the emergence of *Cyrtanthus nutans*
- Determining the influence of fire and defoliation on *Cyrtanthus nutans* populations within demarcated experimental plots

- Comparing plant numbers, seedling recruitment and reaction of *Cyrtanthus nutans* to treatments over two growing seasons within demarcated experimental plots

## 5.3 MATERIALS AND METHODS

### 5.3.1 Study area

The study area for the duration of the experimental was situated at the farm, Lerryn 8602, Dundee, KZN (Chapter 3, Figure 3.3), owned by Mr Hein Potgieter of Drafstap Boerdery cc. The farm is situated south east of Dundee town, KZN (S28.1592, E30.3132°). The long-term mean rainfall is 749 mm $a^{-1}$ and the distribution is a typical summer rainfall pattern with conventional rainfall in the months from October to March. The Veld type is classified as Sour Sandveld (Camp, 1999) according to conclusions in Chapter 4 of this dissertation.

### 5.3.2 Rainfall, temperature and relative humidity

Daily climatological data, namely, temperature (minimum and maximum), rainfall and relative humidity (minimum and maximum) were recorded at a central point at the Dundee Agricultural Research Station (DARS), Dundee, KZN (S28° 8.235', E30° 19.021') at the Agricultural Research Council's (ARC) automated weather station. The long term (1968 to 2016) and short term (2012 to 2016) rainfall data were used to determine total, mean, minimum and maximum annual values. In addition, temperature and relative humidity data was analysed for the period 2015 to 2016 for the duration of the experiment.

### 5.3.3 Experimental site and duration

A small unit experiment was carried out on the farm Lerryn 8602, owned by Mr Hein Potgieter of Drafstap Boerdery cc. The farm is situated south east of Dundee town, KZN (S28.1592, E30.3132°) where a known population of *Cyrtanthus nutans* occurred. A randomized block design (RBD) was used to conduct an 18 month study from mid-winter of 2015 through to mid-summer of 2016/17. The study incorporated two winter seasons when the treatment plots (B and BC) were burnt (in August 2015 and August 2016), followed by two growing seasons (spring 2015 and spring 2016), during which post spring rain burns were undertaken (in

September 2015 and September 2016). The site is within five km from the ARC automated weather station mentioned in paragraph 5.3.1.

### 5.3.4 Experimental site design

Within the study site, covered an area of approximately 75 m x 25 m (1875 $m^2$) in size, three separate areas were designated as replications (Figure 5.1). Within each replication, seven 1 m x 1 m (1 $m^2$) quadrates were randomly placed and labelled according to the treatment that was undertaken. Each quadrate was identified according to the treatment or combination of treatments that were undertaken (Figure 5.2). This resulted in a total of seven treatments with three replications and resulted in 21 treatment plots being assessed for their reaction to climate, fire and defoliation.

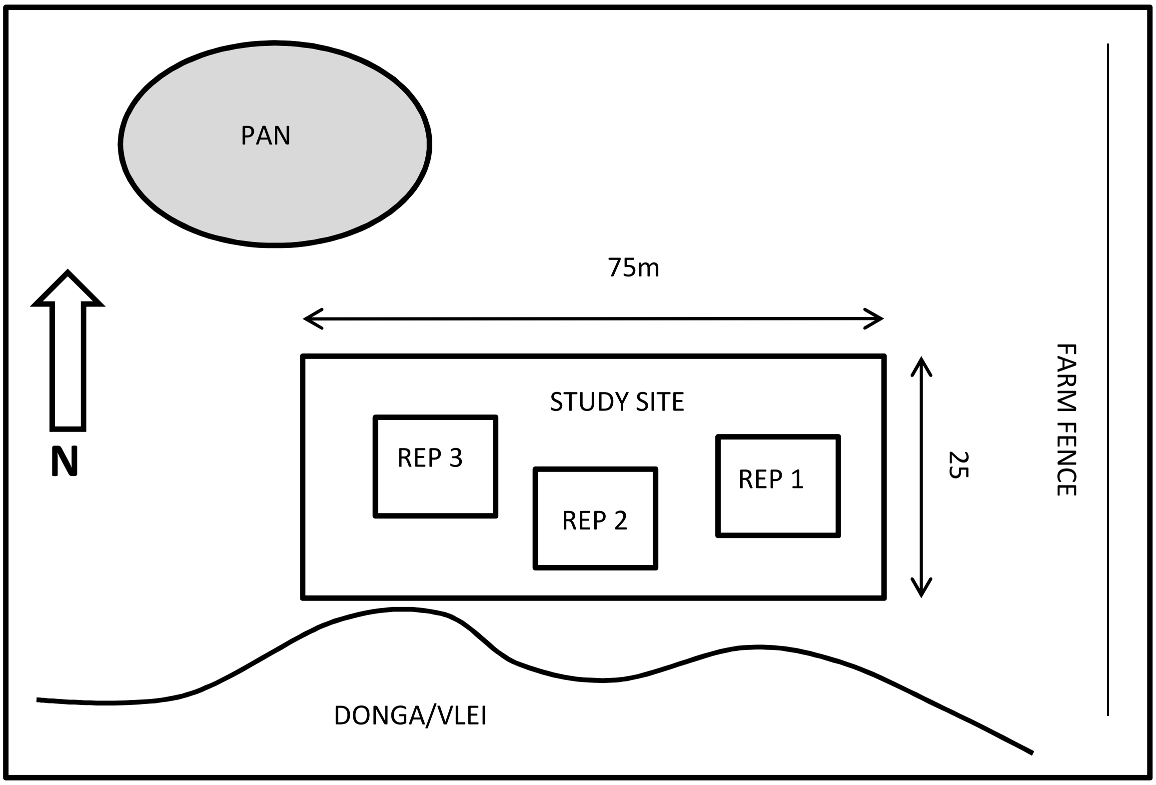


**Figure 5.1: The layout of the study site indicating the different replications in relation to the landscape. The figure is not drawn to scale.**

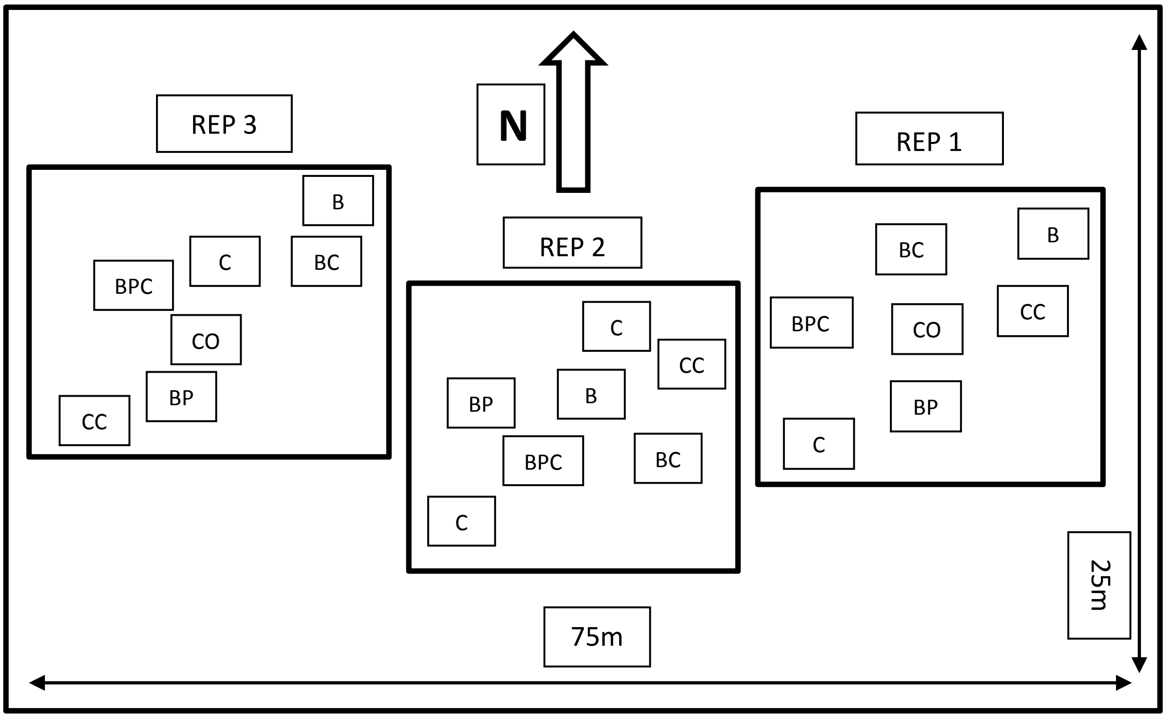


**Figure 5.2: Representation of the experimental layout, indicating the three replications with the treatment plots. The figure is not drawn to scale.**

Each 1 m x 1 m (1 $m^2$) quadrate was demarcated with nylon string and roofing nails and large metal washers were placed at each corner. A cattle tag in the north-easterly corner indicated each plot's identifier. The sides of each quadrate were labelled A - D. (Figure 5.3)

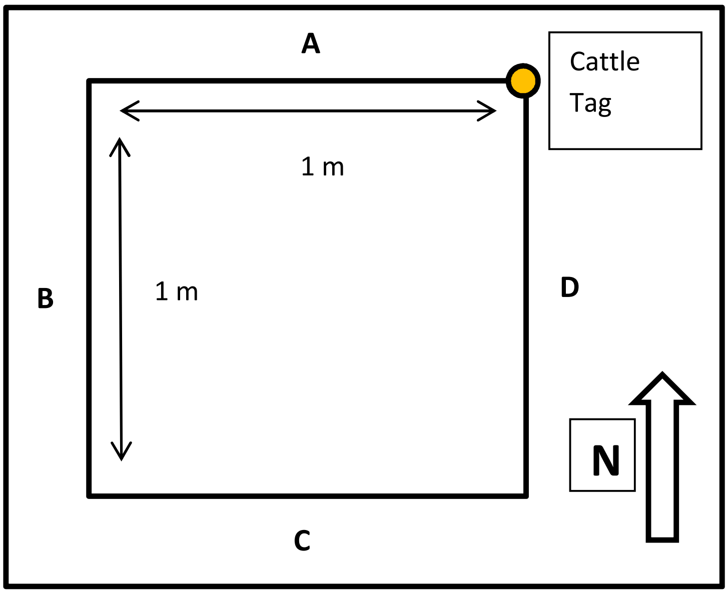


**Figure 5.3: An example of a quadrate indicating the position of the labels for measurements of *Cyrtanthus plants*. The figure is not drawn to scale.**

### 5.3.5 Treatments applied to the experimental plots

For each replication, treatments were applied to six experimental plots (from now on referred to as plots). Treatments involved the inclusion and exclusion of fire and defoliation or a combination of both. As indicated in Table 5.1, the letter (B) represents burning prior to the initial spring rain and (BC) burning prior to the initial spring rain with an exclusion cage to prevent defoliation by large wildlife species (there was no access for cattle into the area). (BP) indicates a burn post initial spring rain and (BPC) a burn post initial spring burn with an exclusion cage to prevent defoliation by large wildlife species. (C) represents the simulation of defoliation through the cutting of the grass and a firebreak was cut for the exclusion of fire. (CC) represents the exclusion of defoliation with an exclusion cage and a firebreak was cut for the exclusion of fire. The control treatment (CO) as a seventh plot, received no treatments. Fire and defoliation were inclusive as no firebreak or exclusion cage were in place.

**Table 5.1: Treatments applied to the seven plots in each replication**

| Plot Identifier | Treatments applied |
|---|---|
| **B** | Pre-spring rain burn<br>(Fire inclusion, defoliation inclusion) |
| **BC** | Pre-spring rain burn and exclusion cage<br>(Fire inclusion, defoliation exclusion) |
| **BP** | Post-spring rain burn<br>(Fire inclusion, defoliation inclusion) |
| **BPC** | Post-spring rain burn and exclusion cage<br>(Fire inclusion, defoliation exclusion) |
| **C** | Firebreak and cut (defoliation)<br>(Fire exclusion, defoliation inclusion) |
| **CC** | Firebreak and exclusion cage<br>(Fire exclusion, defoliation exclusion) |
| **CO** | No treatment<br>(Fire inclusion, defoliation inclusion) |

The temperature of the fire was recorded during the burning using a Fluke 62 MAX Infrared Thermometer® and the temperature of the soil was recorded immediately after the plot was burnt using a handheld pen type thermometer (Major Tech – MT605®). For those plots requiring fire exclusion, firebreaks were cut around the plot. The vegetation was cut starting from a point 0.5 m from the plot boundary so that the microclimate on the immediate boundary of the plot was not affected. All vegetation was cut to approximately 5 cm above the ground.

Defoliation through the simulation of large herbivore grazing or mowing in the plots was undertaken through the cutting of the grass by hand to a height of 5 cm above ground during the initial preparation phase. During the experiment, only indigenous wildlife species (no cattle) had access to the plots at all times. With the plots that required defoliation exclusion, exclusion cages were placed over the plots to prevent grazing by large herbivores. Small rodents and insects had access to the plots. In addition, all herbivorous activity and insect presence in the experimental plot area was recorded.

### 5.3.6 Plot inventory

A weekly photographic and documented inventory for each plot was recorded, from the point of the initial plant's emergence, each subsequent emerged plant, until the last plant emerged. The emergence date of each *Cyrtanthus nutans* plant (leaves, flowers or leaves with flowers) was recorded and the position in relation to the sides of the quadrates were recorded on graph paper, e.g.: A33.4 cm / B27.3 cm Flower (flower indicated with a yellow mark) and C29.4 cm D28.33 cm Leaf (leaf indicated with a green mark) (Figure 5.4). On a weekly basis, each plants existence was verified. Aerial view photographs were taken from the B-side of the quadrates in the morning when shadows on the plot were minimal (Figure 5.5).

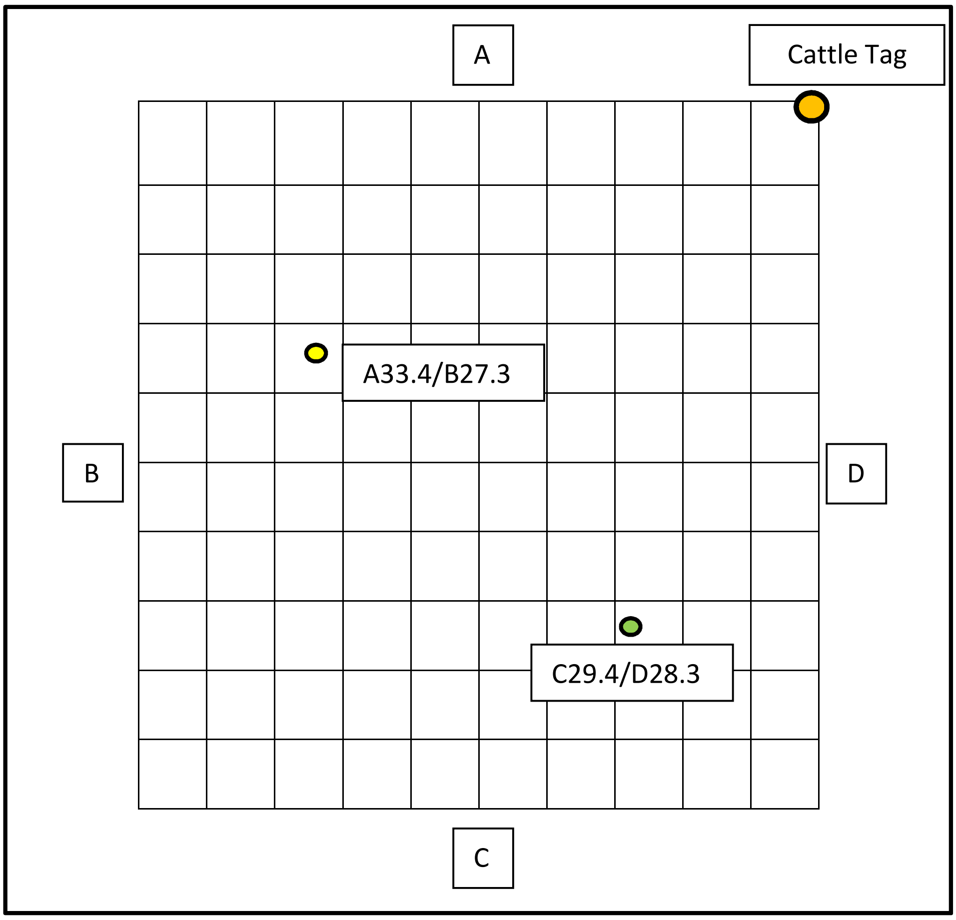


**Figure 5.4: Diagram indicating an example of the position of plants in the plot on the graph paper.**

**Figure 5.5: Aerial view of a plot for the weekly photographic inventory.**

### 5.3.7 Data analysis and statistical design

Climatological data was analysed using GenStat® for Windows (18th Edition) (2015), for the effect climatology combined with treatments had on the emergence for the two week period prior to emergence. With skew distributed counts, a generalized linear mixed model (GLMM) analysis was applied. Use was made of a Stepwise regression analysis with the Poisson distribution and logarithm link function (Dobson, 1983) to test for differences between plant numbers in the seven treatments per season. The number of plants that emerged and the number of plants that existed at the point when seed dispersal ceased were not statistically analysed.

## 5.4 RESULTS AND DISCUSSIONS

### 5.4.1 Rainfall

The long term annual rainfall data for Dundee, KZN for the period 1968 to 2016, as illustrated in Figure 5.6, indicated that the highest and lowest annual recorded rainfall was experienced during 2012/2013 and 2014/2015. In 2012/13, the highest recorded rainfall (1 241 mm) was experienced and two years later in 2014/15 the lowest rainfall (428 mm) was recorded. The long term mean annual rainfall for the area was 749 mm. A trendline indicates the rise in mean rain $a^{-1}$ over the 49 year period.

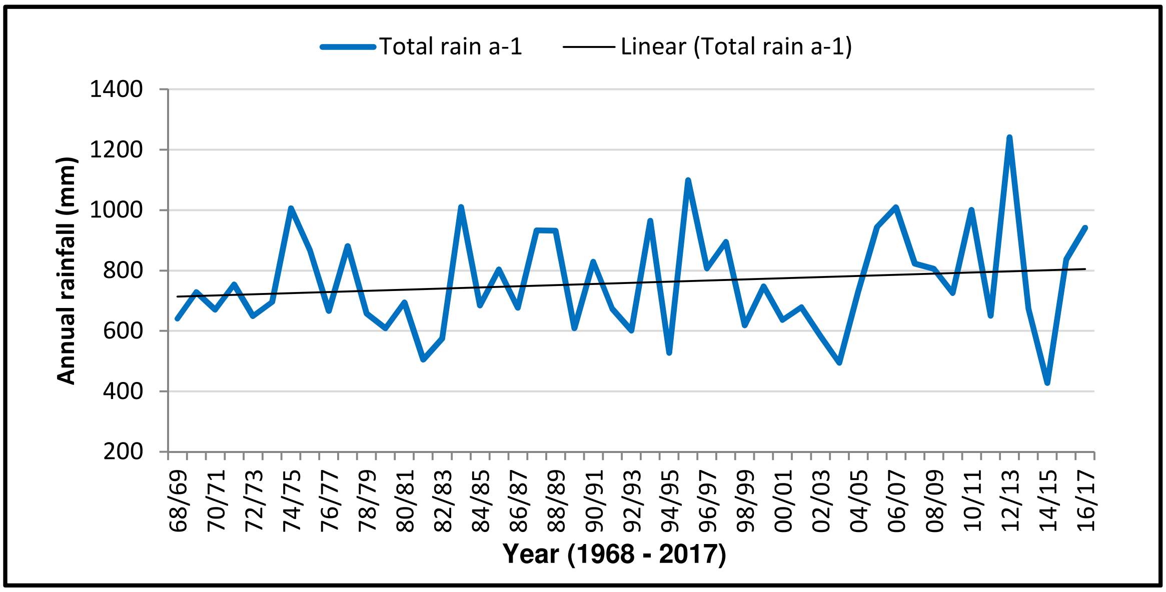


**Figure 5.6: Long term mean annual rainfall for Dundee, KZN with a linear trendline for the period 1968 to 2017.**

Short term rainfall data was recorded for the period 2012 to 2016 indicating seasonal fluctuations and the possible effect it may have on *Cyrtanthus nutans* seed recruitment and development. In 2012 abnormally high rainfall was experienced but low rainfall was recorded for the winter months that followed. Rainfall in the summer season prior to the 2015 trial showed below average rainfall for the winter months of May to August and September. Some carried over moisture might have resulted in not so dry soil conditions in late winter 2015. During the second year of the trial the winter was dry with below average rain, but August and September, which coincidence with the emergence of *Cyrtanthus nutans* plants, received average rain (Figure 5.7).

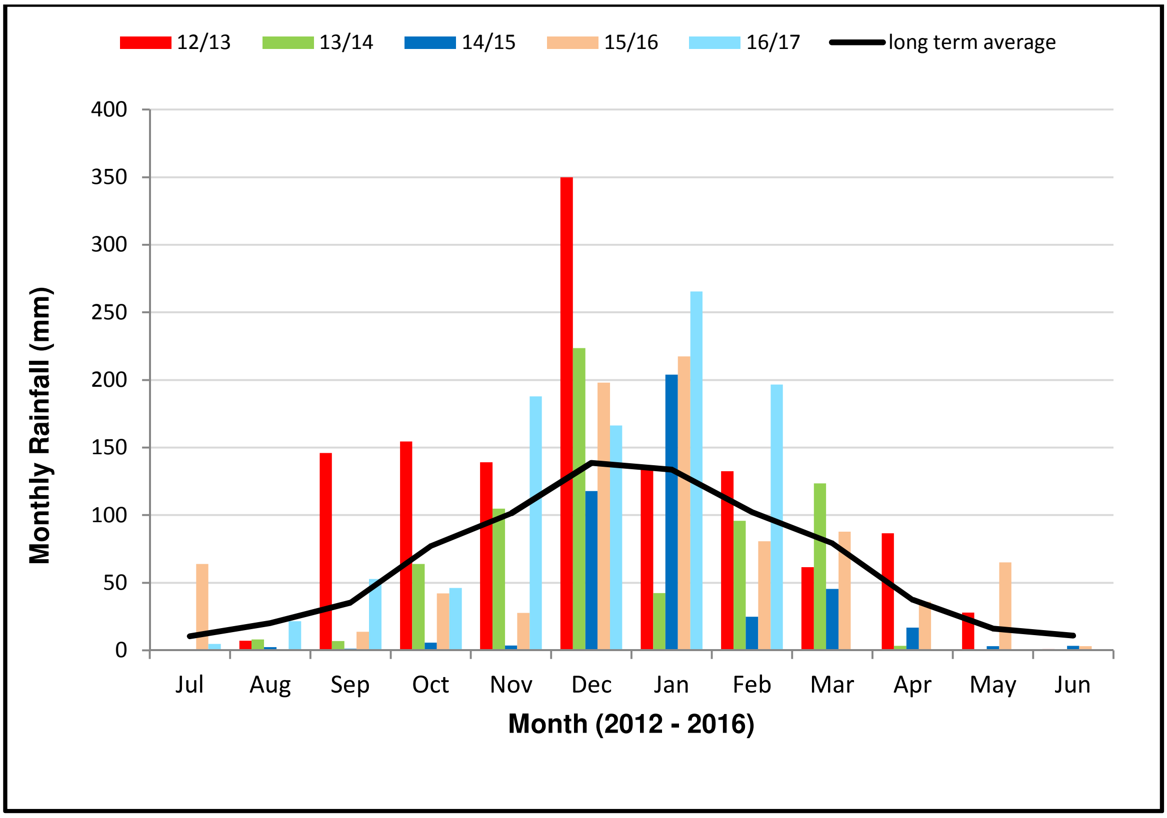


**Figure 5.7: Annual monthly rainfall with a short term mean trendline for the period 2012 - 2017.**

### 5.4.2 Temperature

The mean and absolute maximum and minimum temperatures for each month for the duration of the experiment, 2015 and 2016, are indicated in Table 5.2 and Table 5.3 respectively. For the period 2015 and 2016, the absolute minimum temperature was recorded as -3.99 °C in July 2016 and the absolute maximum temperature was 38.90 °C in January 2016. Maximum temperatures in October to December 2015 and October 2016 exceeded 36 °C with minimum temperatures dropping below freezing (0 °C) in June to August both in 2015 and 2016.

**Table 5.2: Mean minimum and maximum temperatures (°C) for 2015 and 2016 for Dundee Research Station, KZN**

| Months | 2015 | | 2016 | | 2015/16 | |
|---|---|---|---|---|---|---|
| | Minimum | Maximum | Minimum | Maximum | Mean Minimum | Mean Maximum |
| **Jan** | 15.46 | 28.48 | 15.69 | 27.57 | 15.58 | 28.03 |
| **Feb** | 15.08 | 28.15 | 15.76 | 27.99 | 15.42 | 28.07 |
| **Mar** | 14.17 | 26.98 | 14.35 | 27.43 | 14.26 | 27.21 |
| **Apr** | 10.96 | 24.65 | 10.90 | 25.74 | 10.93 | 25.20 |
| **May** | 6.31 | 25.46 | 5.87 | 21.53 | 6.09 | 23.50 |
| **Jun** | 1.86 | 19.93 | 3.48 | 20.96 | 2.67 | 20.45 |
| **Jul** | 3.65 | 20.29 | 2.17 | 19.07 | 2.91 | 19.68 |
| **Aug** | 6.09 | 25.25 | 3.47 | 23.96 | 4.78 | 24.61 |
| **Sep** | 10.05 | 24.63 | 9.58 | 25.42 | 9.82 | 25.03 |
| **Oct** | 11.96 | 28.71 | 11.08 | 25.65 | 11.52 | 27.18 |
| **Nov** | 11.89 | 28.28 | 13.69 | 25.39 | 12.79 | 26.84 |
| **Dec** | 15.81 | 29.67 | 14.79 | 27.42 | 15.30 | 28.55 |
| **Mean Wet*** | 13.70 | 26.45 | 14.24 | 28.27 | 15.58 | 28.03 |
| **Mean Dry**** | 6.49 | 23.37 | 5.91 | 22.78 | 15.42 | 28.07 |

*Mean Wet indicates mean temperatures measured from November of the previous year to April of the current year.

**Mean Dry indicates mean temperatures measured from May to October of the current year.

The plots that required burning before the initial spring rain were burnt in late August (21 August 2015 and 18 August 2016) and those requiring post initial spring rain burns were burnt mid to late September (14 September 2015 and 29 September 2016).

**Table 5.3: Absolute minimum and maximum temperatures (°C) for 2015 and 2016) for Dundee Research Station, KZN**

| Months | 2015 | | 2016 | |
|---|---|---|---|---|
| | Minimum | Maximum | Minimum | Maximum |
| **Jan** | 11.91 | 33.13 | 14.01 | **38.90** |
| **Feb** | 10.48 | 34.83 | 12.54 | 33.01 |
| **Mar** | 7.41 | 31.64 | 7.02 | 33.47 |
| **Apr** | 6.07 | 29.70 | 4.26 | 31.27 |
| **May** | 3.23 | 30.14 | 0.26 | 26.65 |
| **Jun** | -3.03 | 27.18 | -1.46 | 26.00 |
| **Jul** | -1.56 | 27.94 | **-3.99** | 25.94 |
| **Aug** | -2.11 | 31.29 | -2.47 | 30.97 |
| **Sep** | 5.68 | 34.73 | 5.28 | 33.57 |
| **Oct** | 6.83 | 37.47 | 0.74 | 36.21 |
| **Nov** | 4.67 | 38.50 | 10.55 | 34.36 |
| **Dec** | 12.72 | 37.98 | 12.36 | 34.12 |

During the burning, pre and post initial spring rains, the fire temperature was recorded and soil temperatures were taken immediately after the burn had ceased. Slight variations were noted between readings for each plot, with no significant deviations recorded (Table 5.4).

The mean fire temperature and mean soil temperature were not very different on each burn event except on the 18 August 2016 when both parameters recorded cooler temperatures. Minimum and maximum day temperatures were slightly lower in 2016.

**Table 5.4: Mean fire, soil and day temperatures (°C) during the burns**

| Treatment | B and BC | | | | BP and BPC | | | |
|---|---|---|---|---|---|---|---|---|
| Date of burn | 21 August 2015 | | 18 August 2016 | | 14 September 2015 | | 29 September 2016 | |
| Mean temperature °C | 310 | | 285 | | 332 | | 332 | |
| Mean soil temperature range °C | 39.4 | | 37.7 | | 39.9 | | 39.9 | |
| Day temperature °C | Min | Max | Min | Max | Min | Max | Min | Max |
| | 8.5 | 28.4 | 4.6 | 24.5 | 8.3 | 24.4 | 10.3 | 23.1 |

### 5.4.3 Relative humidity percentage

Short term relative maximum and minimum humidity (%) recorded for the period 2015 and 2016 indicated that no notable seasonal dips for maximum relative humidity (%) were experienced in the winter and spring of 2015. However seasonal peaks were recorded for the minimum relative humidity (%) during the same period (Figure 5.8).

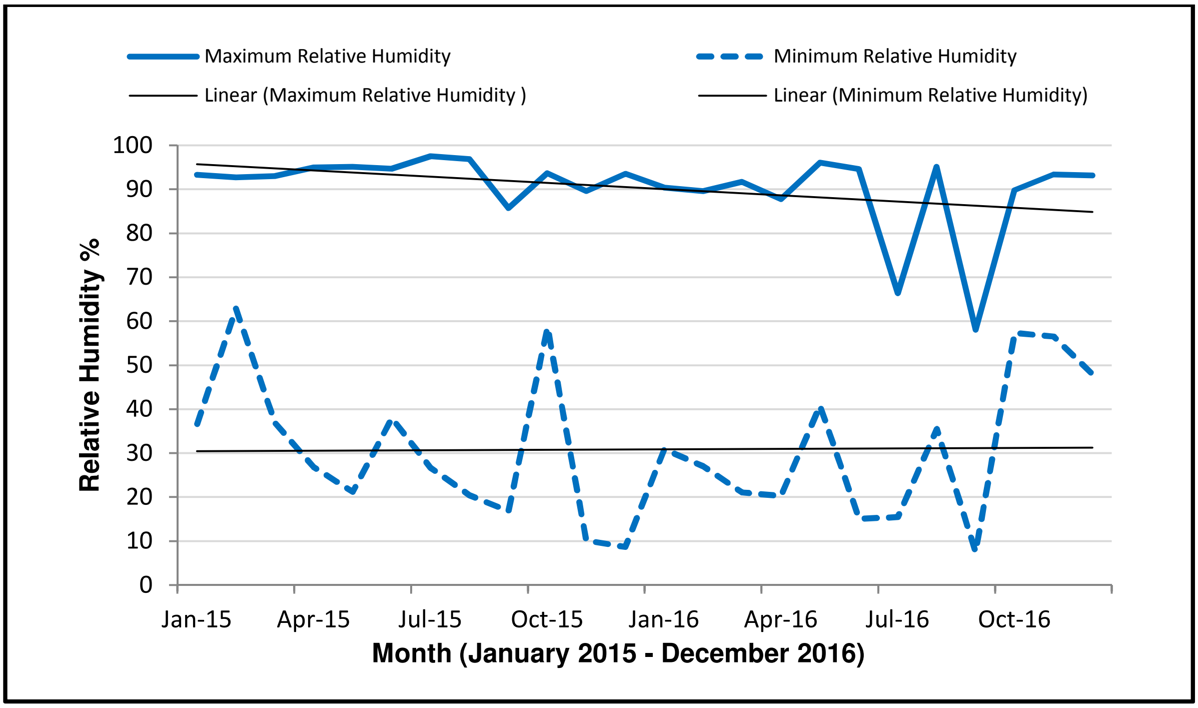


**Figure 5.8: Maximum and minimum relative humidity (%) for the period January 2015 to December 2016.**

Overall, short term climatological factors that are lower than the annual mean can have a negative effect on population growth. Low monthly rainfall in conjunction with high temperatures can inhibit the growth of the plants to seed development stage. In addition, short to midterm low rainfall can impede population growth over a few seasonal cycles. (McNeil, 1967) stated that the flowering period of *Cyrtanthus* species is short-lived due to its reliance on rainfall.

### 5.4.4 Plant emergence in treatments and climatological correlation

For the duration of the experiment in both years, the date of initial flower emergence was recorded at Lerryn farm (Table 5.5). *Cyrtanthus nutans* flowers emerged in early September in both trial years. In 2012 to 2014, initial flowers in the same population in which the experiment was done in 2015 and 2016, emerged between 14 September (2012) and 26 September (2014), both dry winters. These results are supportive of statements made by Reid and Dyer (1954) that *Cyrtanthus nutans* flowers in late August to October. Craib (2004) described *Cyrtanthus galpinii* as also flowering at the end of winter when veld is at its driest.

**Table 5.5: Initial emergence dates of *Cyrtanthus nutans* flowering plants for the period 2015 to 2016 at the experiment site**

| Year | Date of initial emergence |
|---|---|
| 2015 | 9 September |
| 2016 | 8 September |

Daily analysis of climatic data was done for three weeks prior to the expected emergence. In 2015 early rainfall occurred (8.64 mm) accompanied by a rise in minimum relative humidity (%) to more than 75% over a two day period occurred four days prior to plant emergence. This, as expected, was followed by a steady increase in maximum temperature (Figure 5.9).

The early emergence of plants in 2016 occurred after only a minor peak in minimum relative humidity coupled with an increase in maximum temperature with no rainfall. However the 20.3 mm of rain recorded in August 20$^{th}$ may have provided sufficient soil moisture for the stimulation of plant emergence. Minimum temperatures were also just above 0 °C in the last week of August (Figure 5.10).

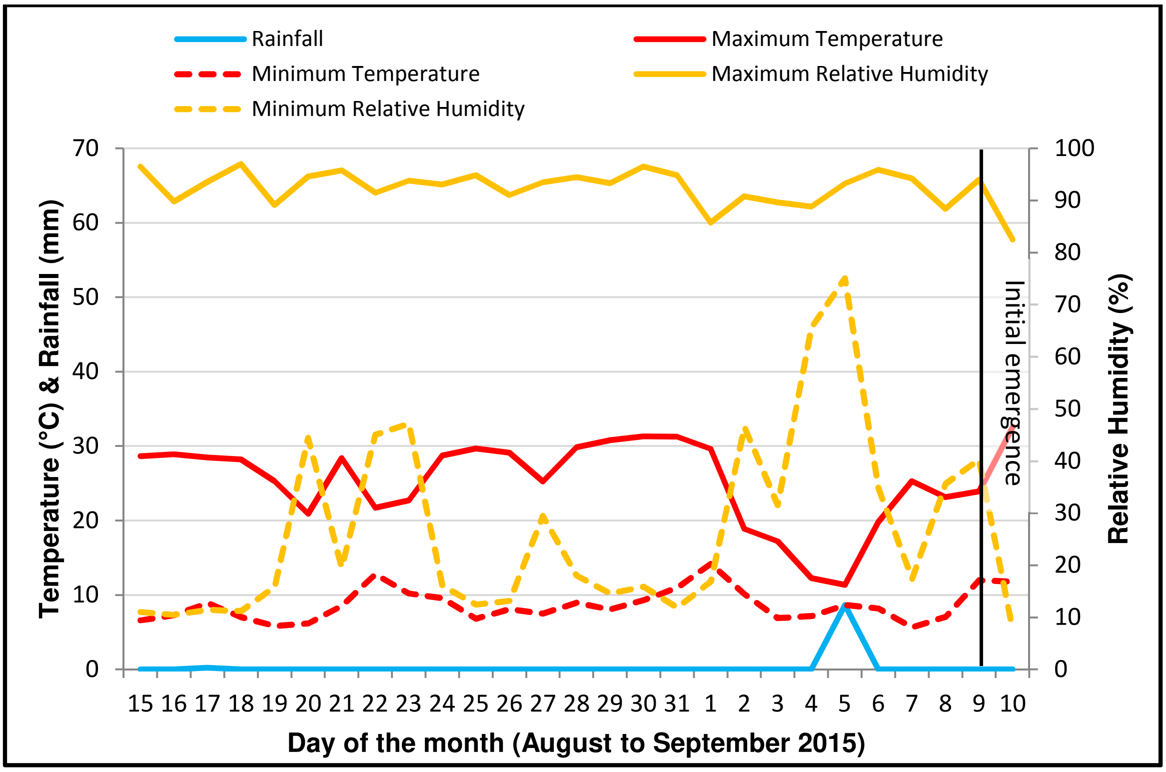


**Figure 5.9: Climatic data preceding plant emergence in September 2015.**

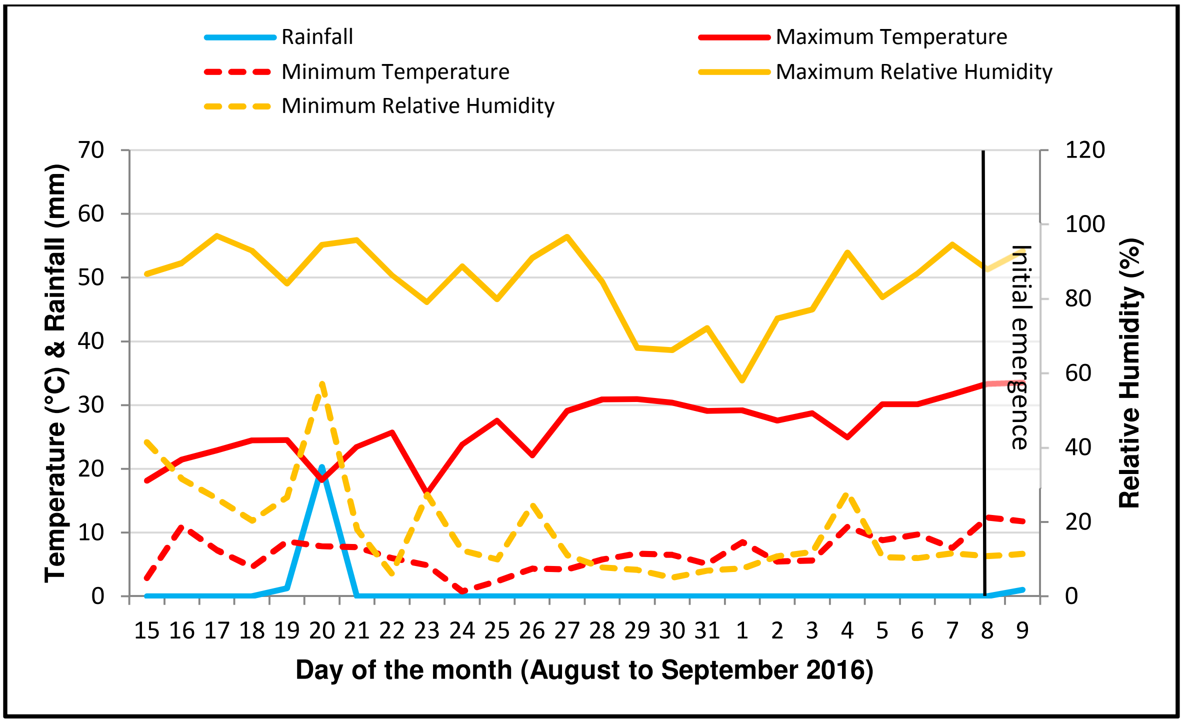


**Figure 5.10: Climatic data preceding plant emergence in September 2016.**

As plants emerged, they were counted and noted for specific position in the experiment. Figure 5.11 and Figure 5.12 indicated the time of emergence of plants till seven weeks after first emergence in the different treatments for 2015 and 2016.

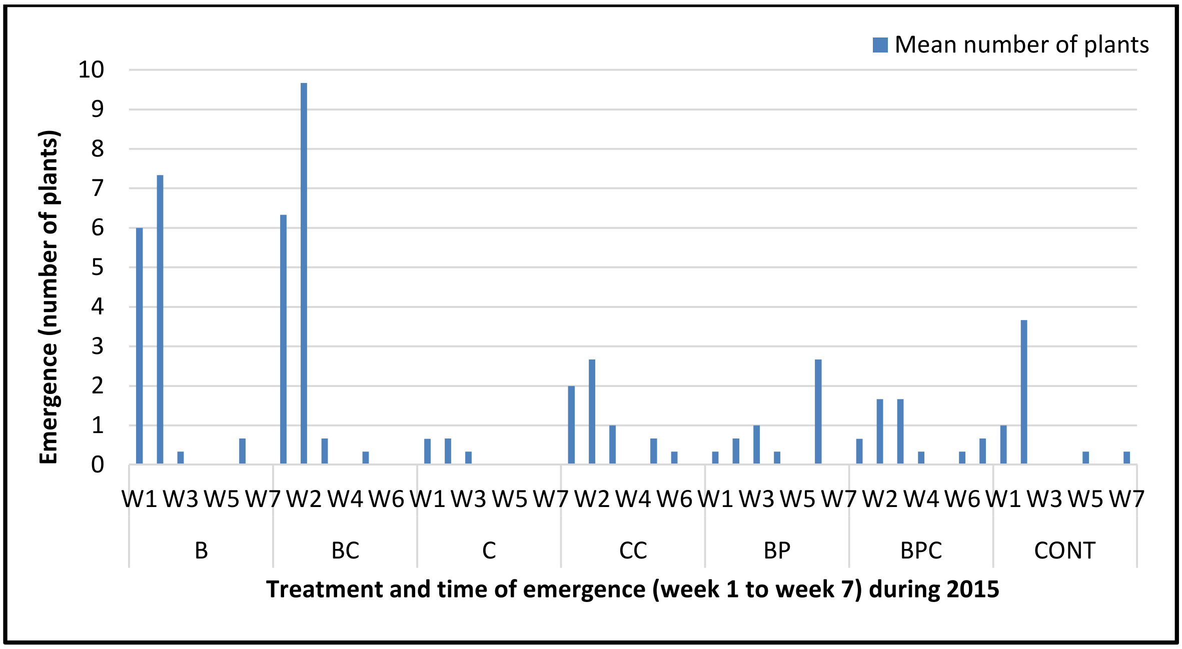


**Figure 5.11: The emergence of plants (mean number) from first emergence date for seven weeks in each treatment for 2015.**

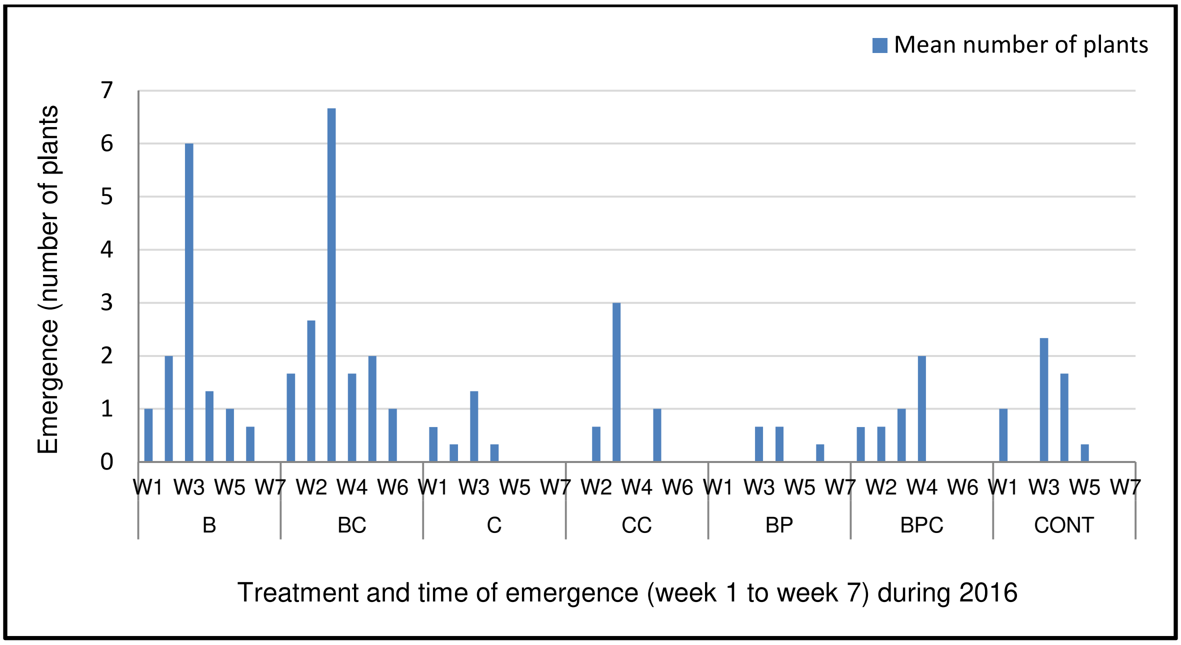


**Figure 5.12: The emergence of plants (mean number) from first emergence date for seven weeks in each treatment for 2016.**

Analyses of the data for the 2015 year showed that nearly 80% (total change less residual) of the variation in plant emergence was accounted for by mean weekly minimum relative humidity, the mean weekly relative humidity, mean weekly minimum temperature and mean weekly rain two weeks before emergence was recorded, as well as the treatment effects (Table 5.6). This indicates that in 2015 minimum relative humidity was highly significant ($P < 0.001$) in the emergence of plants and secondly in conjunction with treatments.

**Table 5.6: Accumulated analysis of deviance - 2015 (Annexure E1)**

| Treatment and climatological factors (change) | Approx. $chi^2$ probability P-value |
|---|---|
| Mean minimum relative humidity | < 0.001 |
| Mean minimum relative humidity with treatment | < 0.001 |
| Mean minimum relative humidity two week period before | 0.015 |
| Mean minimum temperature two week period before | 0.111 |
| Mean minimum temperature | 0.009 |
| Mean rainfall two week period before | 0.034 |
| Mean minimum temperature with treatment | 0.245 |
| Mean minimum temperature two week period before with treatment | 0.006 |

In 2016 at the time of recording, 56% (total change less residual) of the variation in plant emergence was accounted for by mean weekly rainfall, two weeks before emergence as well as the treatment effects indicating high significance ($P < 0.001$ (Table 5.7).

In 2016 the rainfall experienced in the two week period before emergence had a highly significant influence on emergence ($P < 0.001$) in conjunction with treatments, but also overall. The moisture was substantial in providing ideal environmental conditions for the emergence of plants. Comparing August rainfall conditions over several years, August 2016 was the only month out of analysed months with notable rainfall (Table 5.7).

**Table 5.7: Accumulated analysis of deviance - 2016 (Annexure E2)**

| Treatment and climatological factors (change) | Approx. $chi^2$ probability P-value |
|---|---|
| Mean rainfall two week period before | < 0.001 |
| Mean rainfall two week period before with treatment | < 0.001 |
| Mean rainfall | 0.133 |

The combination of 2015 and 2016 data indicated the significance of treatments and mean minimum relative humidity, as well as the rainfall experienced in late August 2016 (Table 5.7).

**Table 5.8: Accumulated analysis of deviance - 2015 and 2016 combined (Annexure E3)**

| Treatment and climatological factors (change) | Approx. $chi^2$ probability P-value |
|---|---|
| Treatment | < 0.001 |
| Mean minimum relative humidity | < 0.001 |
| Mean rainfall two week period before | < 0.001 |
| Mean maximum relative humidity | 0.007 |
| Mean minimum relative humidity with treatment | 0.021 |
| Mean minimum temperature | 0.059 |

The significance of minimum relative humidity (%) ($P < 0.001$) for the emergence of plants in 2015 was notable. In 2016 the rainfall in mid-August provided enough moisture for the emergence of plants and the combination of data for the 2015 and 2016 seasons highlighted the importance of treatments in conjunction with climatological factors.

### 5.4.5 Plant population numbers in treatments

A comparison between the 2015 and 2016 mean plant population numbers that emerged for each treatment was recorded. Plants were counted as per the weekly inventory in the three groups of leaves, flowers and leaves with flowers. The mean number of leaves in the pre-spring burns, B and BC were notably higher than in the post-burn treatments, respectively nine in 2015 and 11 in 2016 in the B treatment, and 13 in 2015 and 10 in 2016, compared to five or less in most of the other treatments the number of leaves were higher in 2015 than in 2016. Only in the B treatment and in the C treatment was this not the case (Figure 5.13). Although the mean number of flowers recorded for each treatment in 2015 did not exceed two, the 2015 pre-spring burn treatments, B, BC and CC treatments (two each) and treatments C and CO (one each) were higher than the non-existent flowers recorded in the post-spring burns BP and BPC. In 2016, five of the seven plots recorded a mean of three or less plants and in comparison to 2015, plots B and BC had fewer emerged flowers emerged (zero and one respectively). Treatment CC (three flowers) recorded the highest mean number of emerged flowers (Figure 5.14).

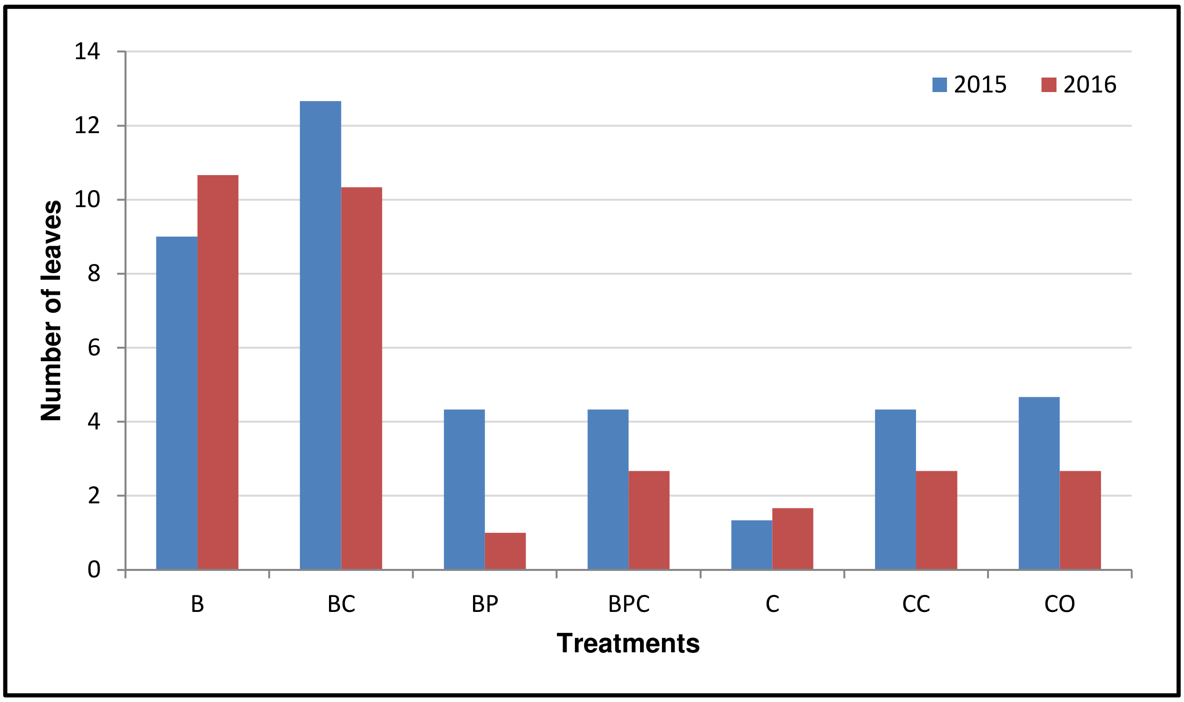


**Figure 5.13: Mean number of *Cyrtanthus nutans* leaves emerged in the different treatments in 2015 and 2016.**

The mean number of leaves with flowers for the pre-spring burn treatments, B and BC were significantly higher than any other treatments with two each for 2015 and three and five for 2016 respectively. No notable difference was seen for the remaining treatments in 2015 or 2016, with mean numbers less than one (Figure 5.15).

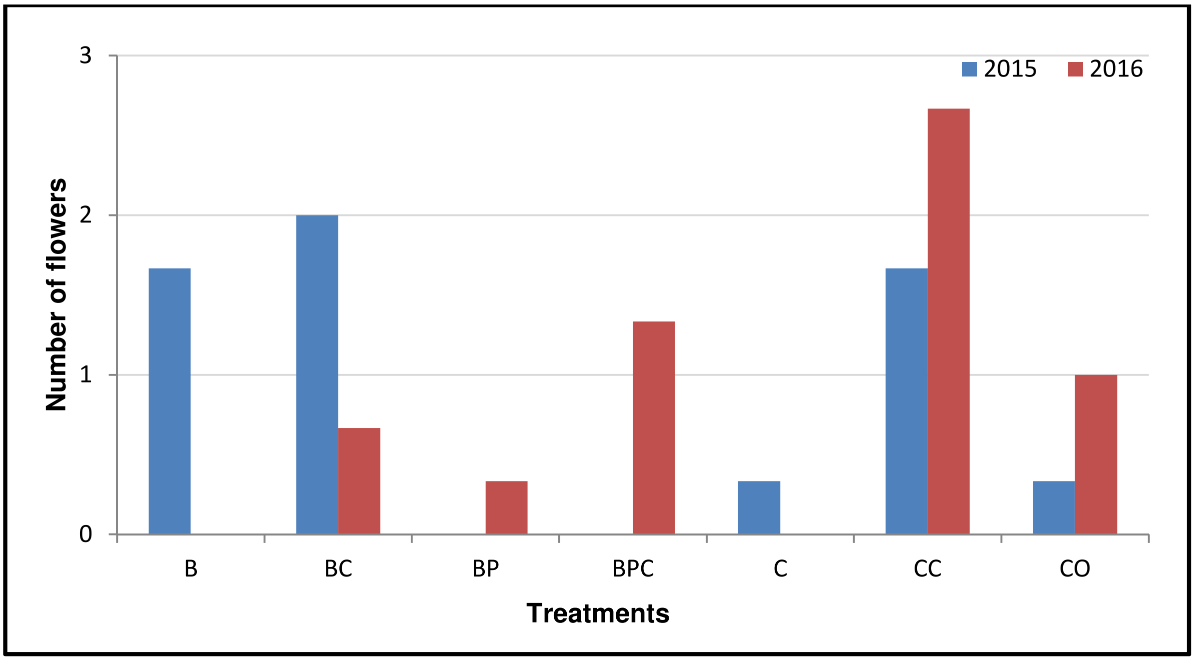


**Figure 5.14: Mean number of *Cyrtanthus nutans* flowers emerged in the different treatments in 2015 and 2016.**

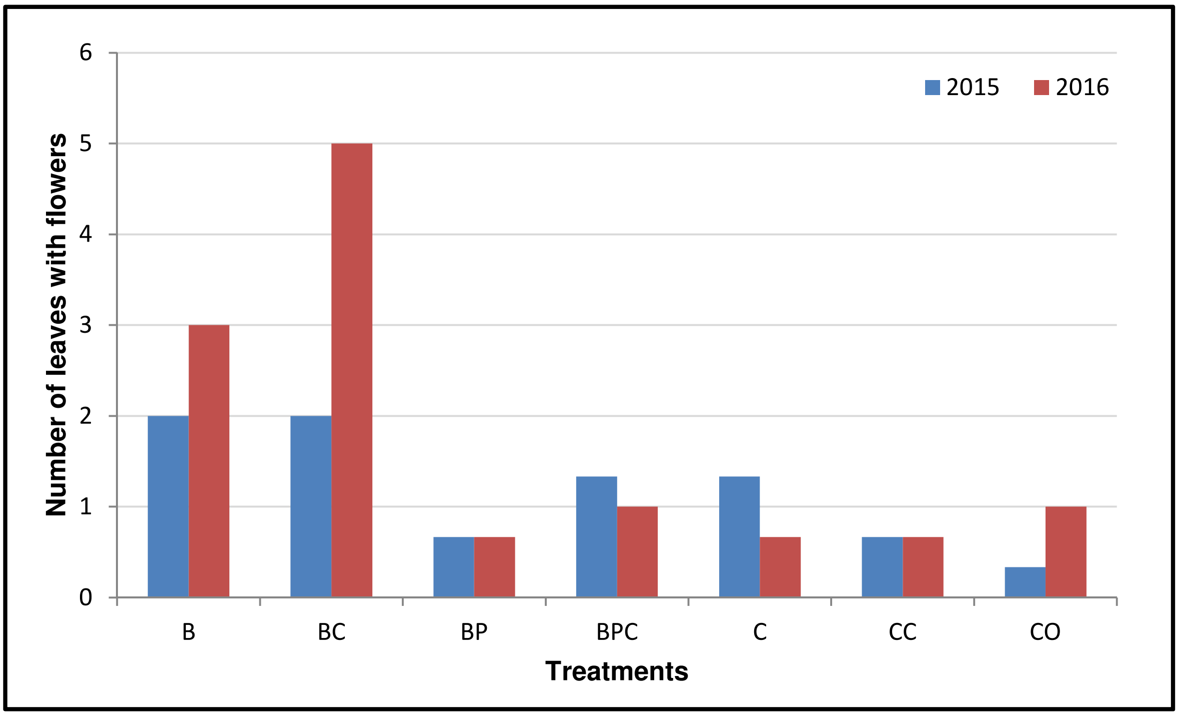


**Figure 5.15: Mean number of *Cyrtanthus nutans* leaves with flowers emerged in the different treatments in 2015 and 2016.**

Comparison between the 2015 and 2016 mean number of emerged *Cyrtanthus nutans* plants indicated a significantly higher number in treatments B and BC with 13 and 17 in 2015 and 14 and 16 in 2016 respectively, when compared to the other treatments which recorded six plants or less (Figure 5.16). Correlation with the work of Craib (2004) indicates a similarity with studies on *Cyrtanthus galpinii*, where plants located in the burnt areas flowered very well, particularly when grass cover had previously been dense. Areas with dense grass cover that had not been burnt had plants that failed to flower yet areas with sparse grass cover had mature bulbs that flowered.

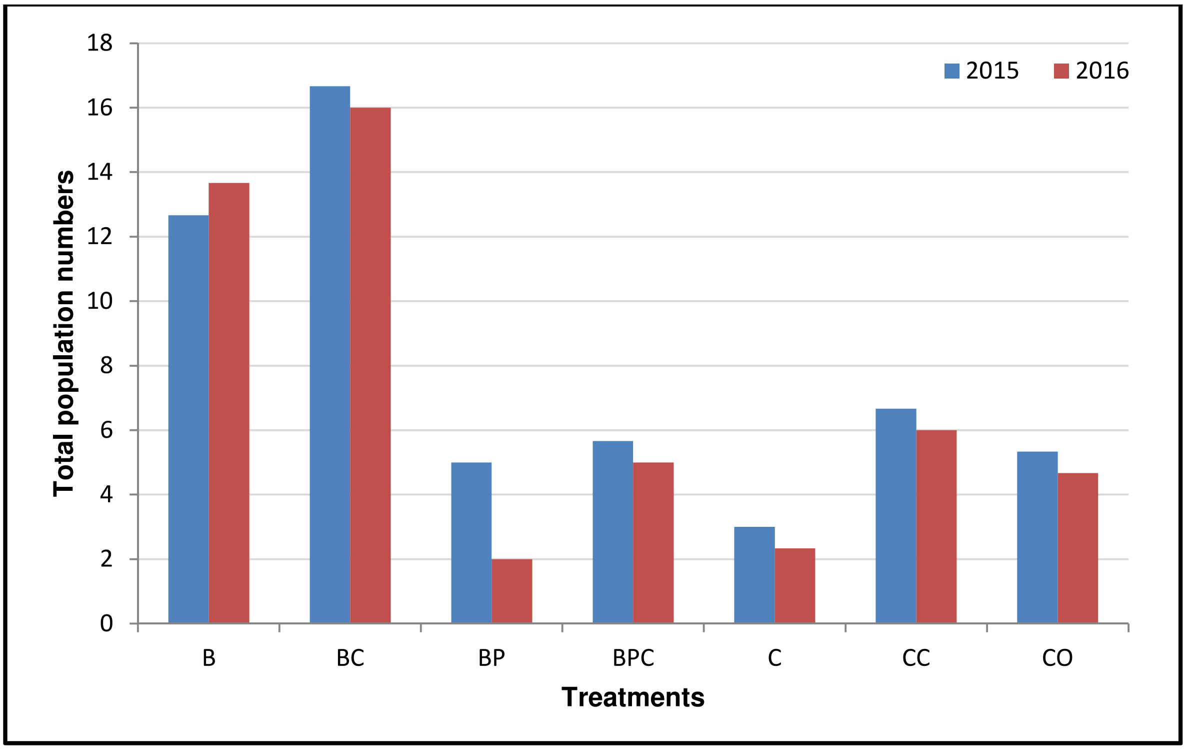


**Figure 5.16: Mean number of total plant population of *Cyrtanthus nutans* plants emerged in the different treatments in 2015 and 2016.**

Comparing the two treatments through statistical analysis, there was very strong evidence ($P < 0.001$) (Annexure E4) that the treatments differed in the emergence of the plants. Treatments B and BC did not differ significantly from each other, but emergence was significantly higher ($P < 0.001$) than the rest of the treatments. Emergence for the post-spring rain (BP and BPC) and CO treatments did not differ significantly and was also similar in range to the fire exclusion combined with defoliation inclusion/exclusion plots (C and CC). The minimum relative humidity coupled with 8.7 mm of rainfall in the spring of 2015 was indicated as the stimulus for initial plant emergence, however burn treatments were the main stimulant for plant emergence during the season as lower than average rainfall during July to November 2015 coupled with the post-spring rain, defoliation and control treatments were insufficient for plant emergence (Table 5.9).

**Table 5.9: Differences in the total number of plants for seven treatments for 2015 (Annexure E4)**

| Treatment | Mean emergence |
|---|---|
| B | $11.239^{a}$ |
| BC | $14.788^{a}$ |
| BP | $4.437^{b}$ |
| BPC | $4.732^{b}$ |
| C | $2.662^{b}$ |
| CC | $5.915^{b}$ |
| CO | $4.732^{b}$ |

- Letters with the same superscript indicate no significant difference

Similar results were seen in the 2016 data analysis; B and BC differed from the remaining treatments, and were significantly higher ($P < 0.001$) than the rest of the treatments. BP and CC differed slightly to treatments BPC, C and CO (Table 5.10).

**Table 5.10: Differences in the total number of plants for seven treatments for 2016 (Annexure E4)**

| Treatment | Mean emergence |
|---|---|
| B | $12.016^{a}$ |
| BC | $14.068^{a}$ |
| BP | $1.758^{c}$ |
| BPC | $4.396^{bc}$ |
| C | $2.052^{bc}$ |
| CC | $5.275^{b}$ |
| CO | $4.103^{bc}$ |

- Letters with the same superscript indicate no significant difference

The combination of the two seasons resulted in treatments B and BC differing from each other but with different values, however they were significantly different to the other treatments. The remaining treatments all differed significantly to each other (Table 5.11)

Only the main effect of treatment differences was significant ($P < 0.001$). Treatments BC and B did not differ significantly but was highly significantly different ($P < 0.001$) in plant numbers than the other treatments providing evidence that burning with or without defoliation was significant in the emergence of *Cyrtanthus nutans* plants throughout the growing season (Table 5.11).

**Table 5.11: Differences in the total number of plants for seven treatments for 2015 and 2016 combined (Annexure E4)**

| Treatment | Value |
|---|---|
| B | $11.621^{a}$ |
| BC | $14.424^{a}$ |
| BP | $2.793^{cd}$ |
| BPC | $4.561^{bc}$ |
| C | $2.337^{d}$ |
| CC | $5.586^{b}$ |
| CO | $4.407^{bcd}$ |

- Letters with the same superscript indicate no significant difference

Burning prior to the initial spring rain and the exclusion of defoliation in the treatment plots was clearly indicated in the graphs above and when statistically analysed as significant ($P < 0.001$) for the emergence of leaves and leaves with flowers. However the emergence of flowers was clearly influenced by the exclusion of defoliation..

### 5.4.6 Survival of plants

The number of plants that initially emerged was compared with the number of plants present at the point when the seeds had finally been dispersed. In 2015, for leaves only, the treatment where the number of leaves emerged equalled the number that survived until the end of the season was treatment BPC (four leaves), the remaining plots all indicated a relatively small loss of leaves (Figure 5.17).

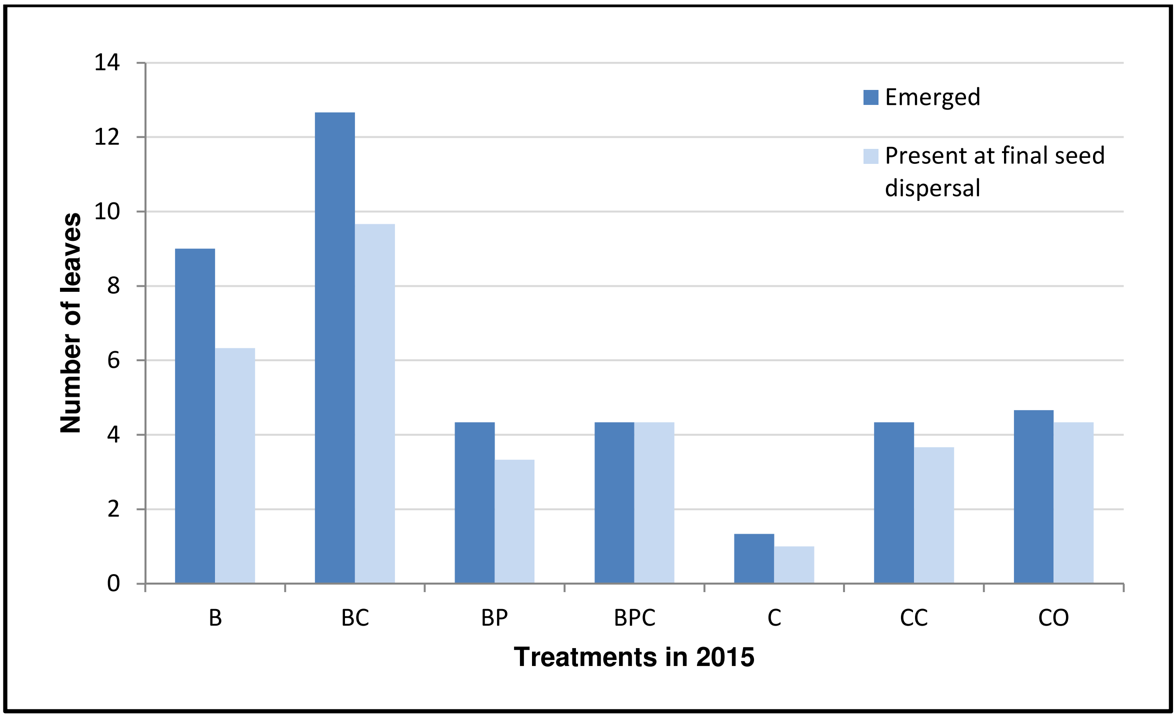


**Figure 5.17: Mean number of *Cyrtanthus nutans* leaves that emerged and were present at the final seed dispersal stage in the different treatments for 2015.**

During 2016, all treatments indicated a decrease in the mean number of leaves. However the percentage loss was minimal in the burn treatments when compared to other treatments (Figure 5.18). An overall comparison indicates that treatments B and BC combined for the two year period, had the highest number of leaves survive (34 leaves from 43 emerged) when compared to other treatments.

When comparing the number of flowers that emerged to the number that survived the season, only two treatments still had intact flowers after the seed dispersal stage, both were protected by exclusion cages (BC and CC). Treatments BP and BPC had no flowers develop during the 2015 season (Figure 5.19).

.

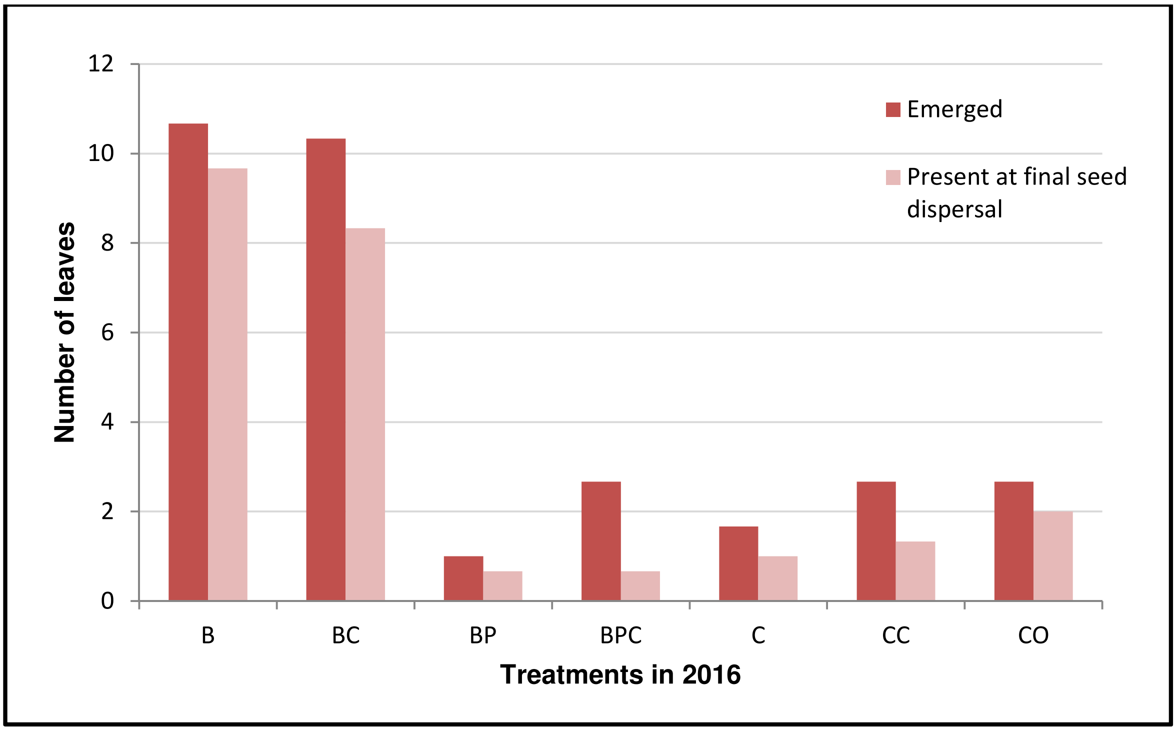


**Figure 5.18: Mean number of *Cyrtanthus nutans* leaves that emerged and were present at the final seed dispersal stage in the different treatments for 2016.**

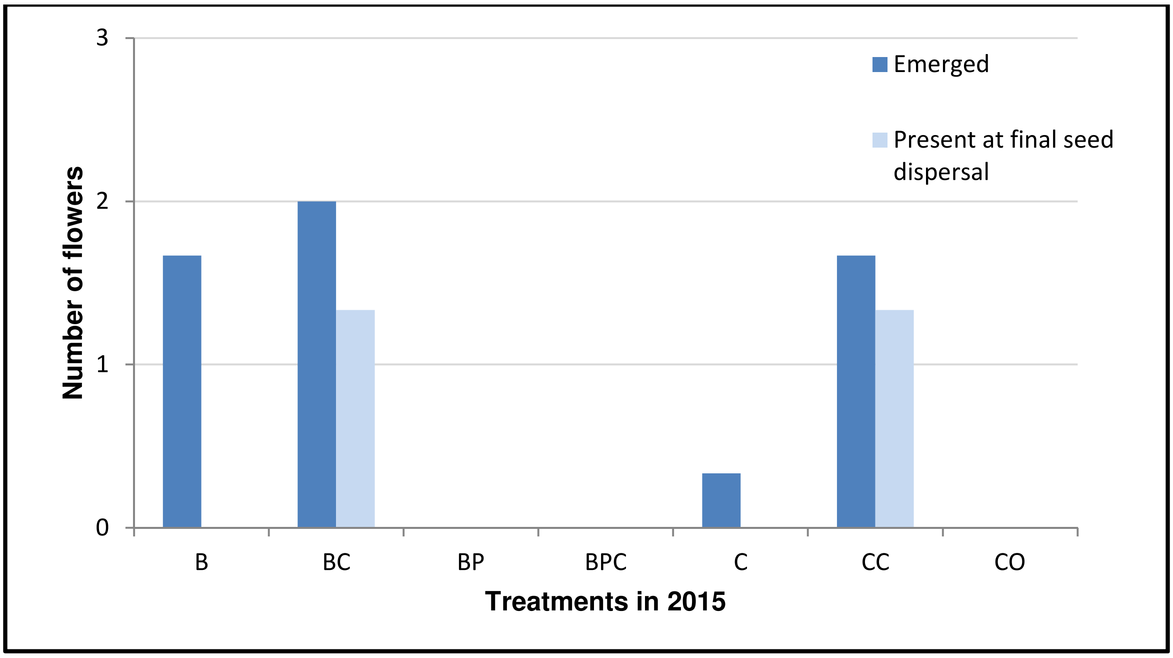


**Figure 5.19: Mean number of *Cyrtanthus nutans* flowers that emerged and were present at the final seed dispersal stage in the different treatments for 2015.**

Similarly, in 2016, all defoliation exclusion treatments and the control treatment still had flowers at the end of the seed dispersal stage with three of the four treatments showing no reduction in the number of emerged flowers at the stage of seed dispersal. Treatments B and C had no flowers develop during the 2016 season (Figure 5.20).

In 2015 all treatments had leaves with flowers emerge and all with the exception of treatment B, had surviving leaves with flowers of one or less (Figure 5.21). Notably in 2016, and with no exceptions, all treatments had a mean value of one leaf with a flower present at the end of the seed dispersal stage, except treatment BC that had a mean number of three (Figure 5.22).

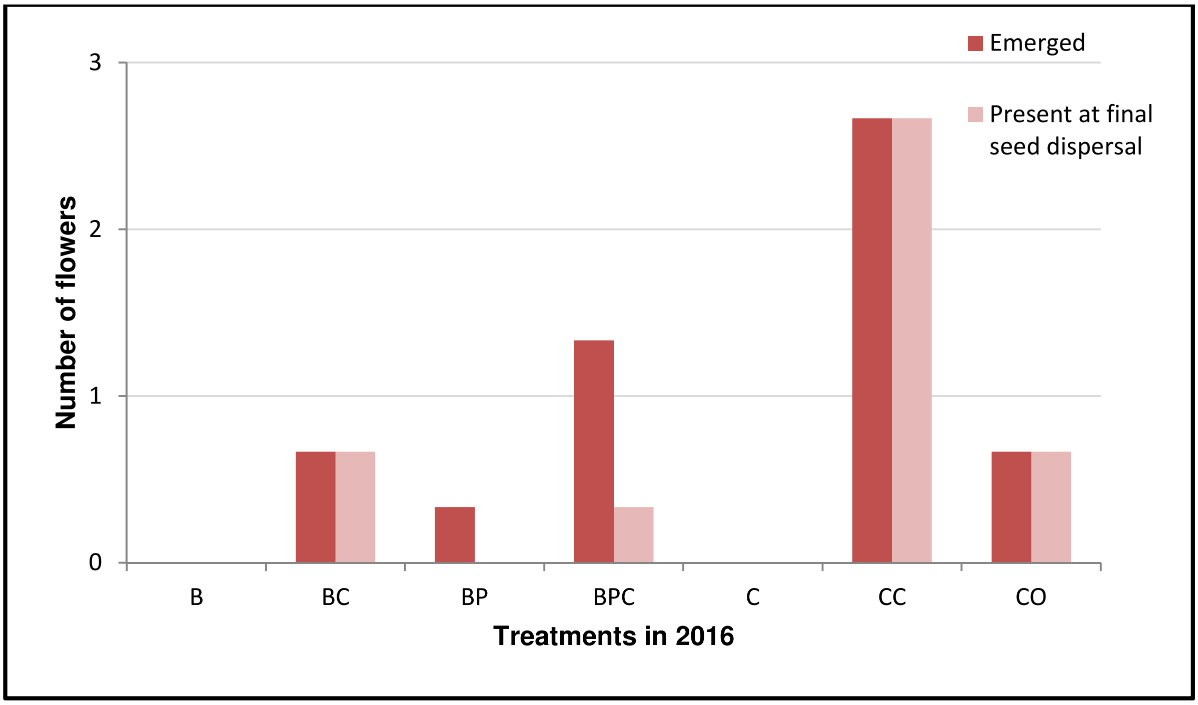


**Figure 5.20: Mean number of *Cyrtanthus nutans* flowers that emerged and were present at the final seed dispersal stage in the different treatments for 2016.**

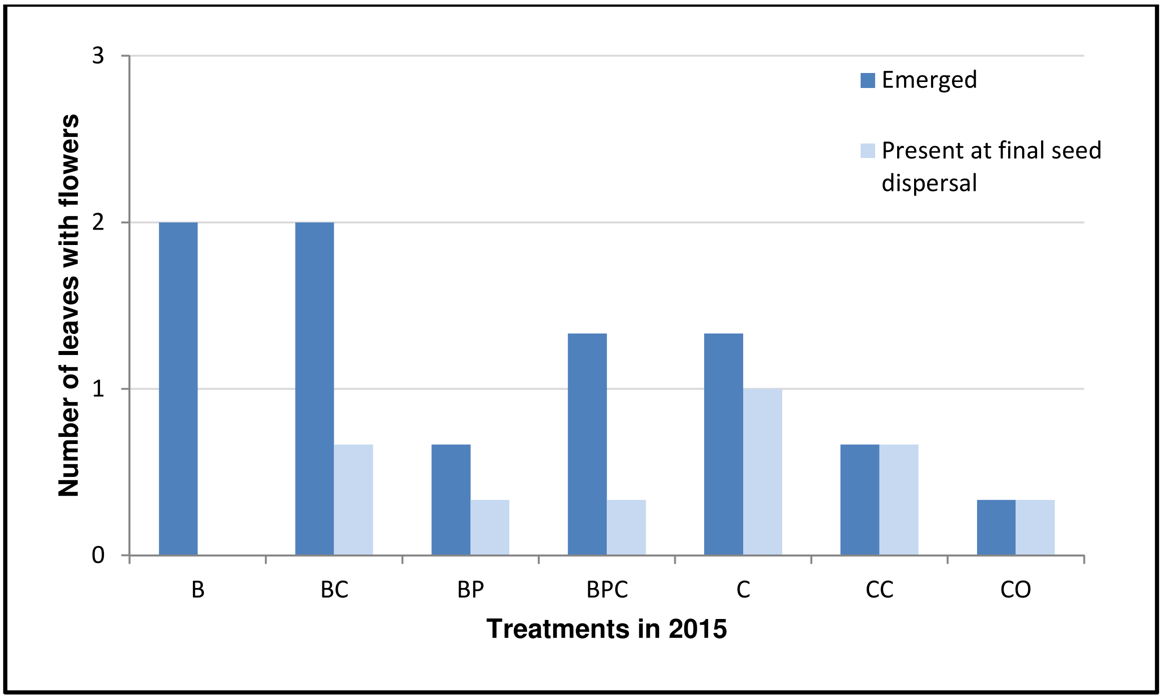


**Figure 5.21: Mean number of *Cyrtanthus nutans* leaves with flowers that emerged and were present at the final seed dispersal stage in the different treatments for 2015.**

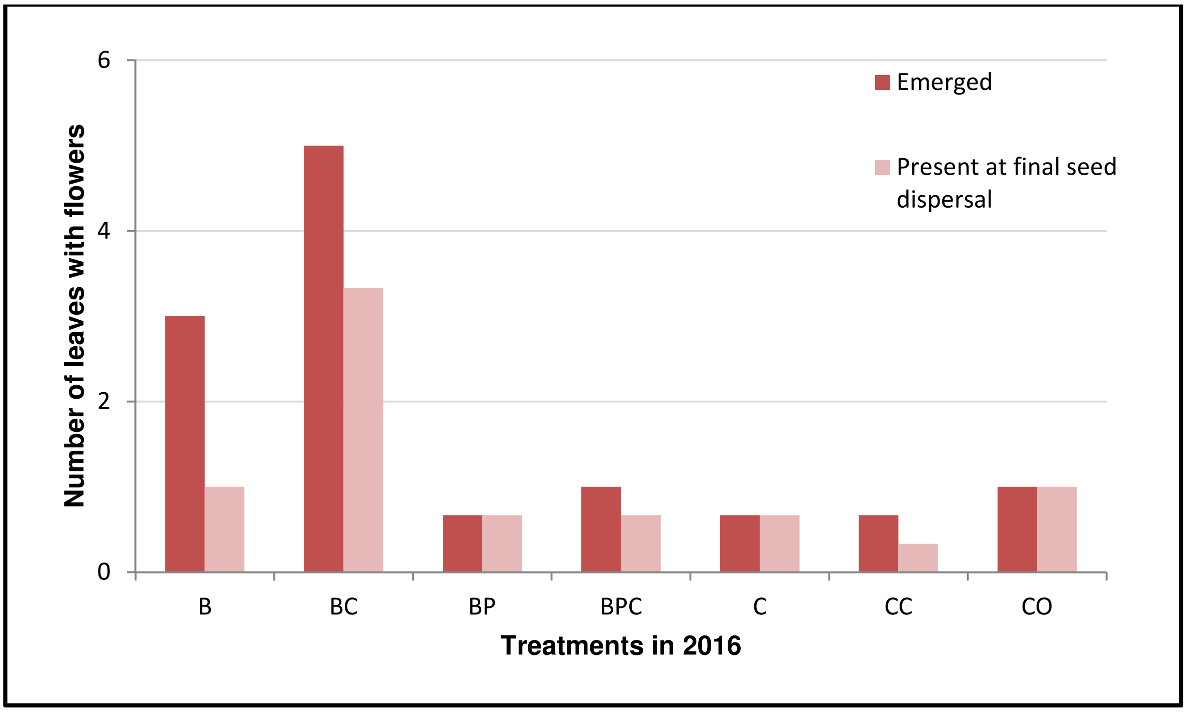


**Figure 5.22: Mean number of *Cyrtanthus nutans* leaves with flowers that emerged and were present at the final seed dispersal stage in the different treatments for 2016.**

The mean total number of plants that emerged for each treatment in 2015 and 2016 were compared. Treatments B and BC were again noticeably higher than any other treatments with mean values of four and six for 2015 and five and five for 2016, respectively.  All remaining treatments for either year indicated values of two or less (Figure 5.23).

Similarly, the mean number of plants that survived the season for 2015 and 2016 in all treatments except B and BC indicated mean values of two or less. Treatments B and BC values were recorded at four and six for 2015 and five and five for 2016 (Figure 5.24).

The uniformity in low survival rates of leaves and leaves with flowers between all the treatments excluding treatments B and BC is indicated in the above graphs. Treatments B and BC for both years is indicative that high emergence rates result in high survival rates due to the burning of the plots.

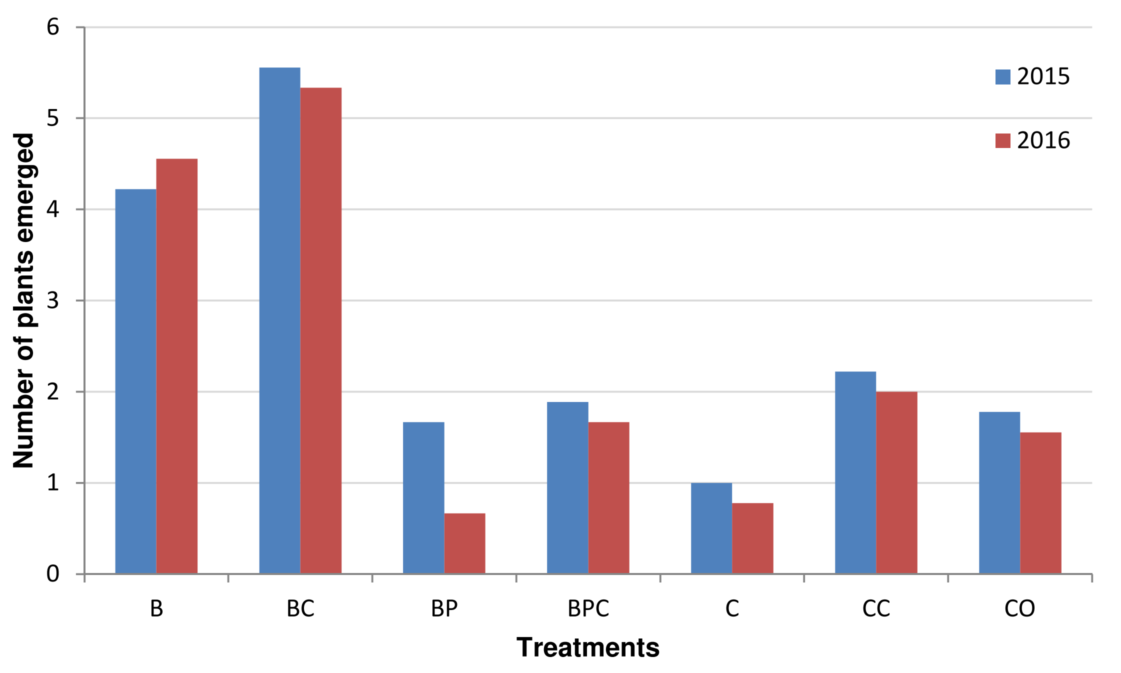


**Figure 5.23: Mean total number of *Cyrtanthus nutans* plants that emerged for the different treatments for 2015 and 2016.**

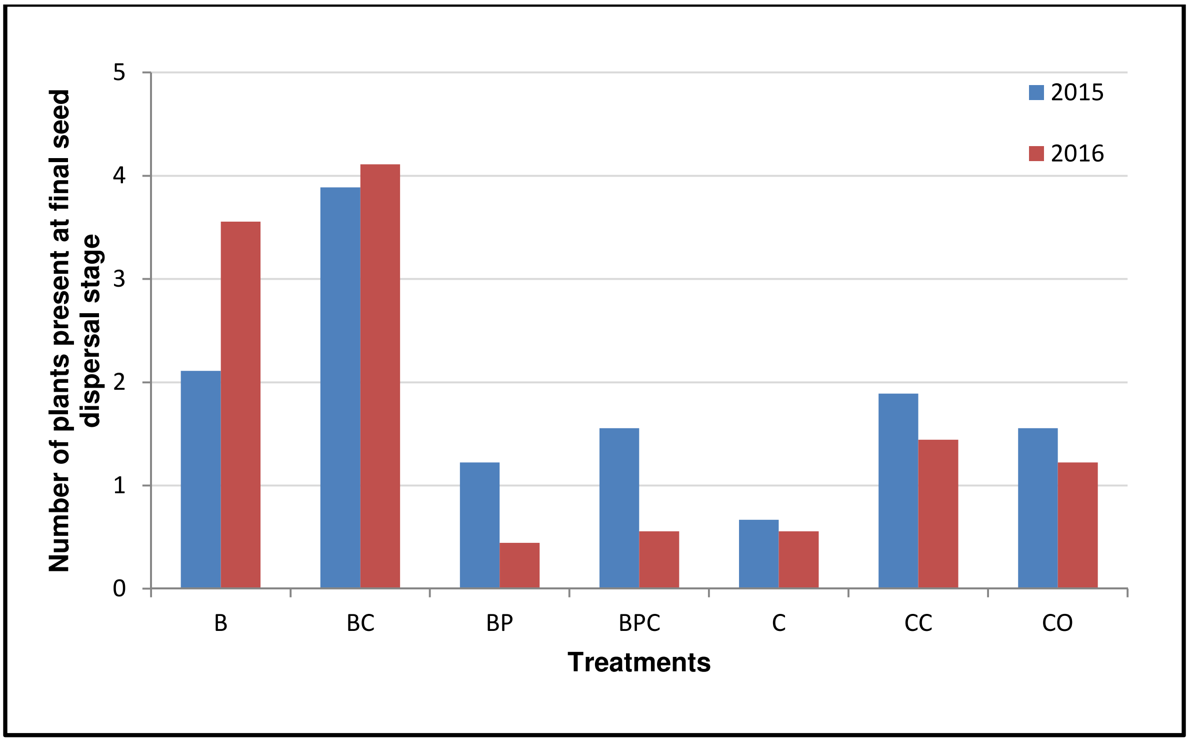


**Figure 5.24: Mean total number of *Cyrtanthus nutans* that were present at the final seed dispersal stage in the different treatments for 2015 and 2016.**

Burning is beneficial to bulbous plants for the clearing of moribund matter and the redistribution of nutrients into the soil. Burning around the first rains is often valuable, however burning at the time that *Cyrtanthus galpinii* plants are in the flower or seed development stage, the entire season's flowers and seed could be lost (Craib, 2004). In this study, it was found that treatments BP and BPC never recovered through the re-emergence of plants in the same year, nor showed recovery in plant numbers in the following season.

Craib (2004) also indicated that the shorter the grass sward and regular grazing by animals may be beneficial to the species in the long term. However it was found with the current study that, treatments that were exclusively cut (C) had lower numbers in the second year than in the first.

Comparison of the plots from 2015 to 2016, indicated that a high percentage of the plants were in almost identical positions. Taking into account the slight variable emergence of the leaf or flower tip and movement from one year to the next of the plot boundary ropes by a fraction due to grass tufts growth and soil compaction or looseness at the four corner nails, the percentage of plants that re-emerged was a factor that contributed to the overall survival of the population. Although below average spring rainfall and extreme spring temperatures (37.4 and 38.5°C in October and November respectively) were experienced during 2015, only 59% of those plants emerged again in 2016 and the remaining plants counted in 2016 were new plants (Figure 5.25).

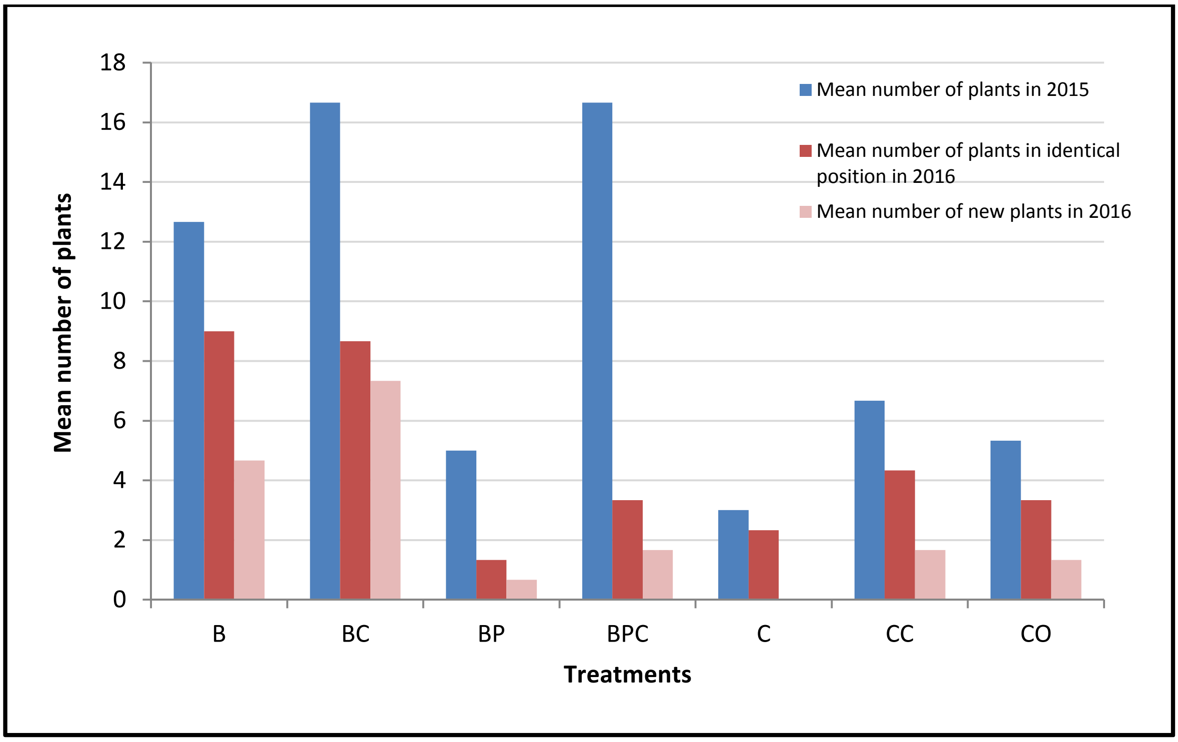


**Figure 5.25: Mean total number of *Cyrtanthus nutans* in identical positions in a comparison between 2015 and 2016 plants together with new plants identified in 2016.**

## 5.5 CONCLUSION

It was apparent that a number of factors whether in conjunction with each other or as a single influencing factor, had an effect on the emergence and survival of *Cyrtanthus nutans*.

Climatic influence, particularly minimum relative humidity (%), played a major role in the emergence of *Cyrtanthus nutans* plants. Rainfall in late August or early September together with minimum temperatures above 10 °C provided sufficient soil moisture and temperatures to stimulate growth. Rainfall in conjunction with mean daytime temperatures (mean values for the ten year period 2012 to 2016 were 25.2 °C, 25.5 °C and 26.4 °C in September, October and November, respectively) provided the factors that determined short term stability of the population, with fluctuating changes in rainfall and temperature during drought years reduced seedling recruitment for future populations.

The long term sustainability of plant populations was affected by climatological factors. Minimum relative humidity was the key determinant in the emergence of plants. However growth and development requires adequate average rainfall to sustain populations.

Burning, undertaken prior to the initial spring rain had a positive effect on the emergence of plants in terms of reduced competition from moribund material. Burning after the initial spring rains had an adverse effect on the population. Flowers damaged prior to the seed dispersal stage reduced the potential seedling recruitments in the following season. A small percentage of bulbs that lost flowers from the burning, still developed leaves afterwards, reducing the potential of seed development in the following season.

No significant effects were seen from defoliation as a single factor in the treatment plots, however when combined with exclusion from defoliation, increased both emergence in the following season and survival of seed bearing flowers. Herbivory from the wildlife and insects in the plots was minimal, but could be negatively affected if heavy grazing by livestock occurred. This needs to be addressed in further studies.

# CHAPTER 6

# CONCLUSION

## 6.1 INTRODUCTION

The objective of this research work was to determine the effects that abiotic, biotic and anthropogenic influences have on the *Cyrtanthus nutans* population as well as its distribution patterns. Historical distribution was recorded initially as abundant in the Vants Drift area (Reid and Dyer, 1954) and later described by Scott-Shaw *et al.* (2007) as disjunct and only known from five locations in Dundee, KwaZulu-Natal (KZN) and Piggs Peak, Swaziland. In this study, the current distribution patterns were found to be fragmented due to land use change and the question arises what does the future hold for *Cyrtanthus nutans*. Long term observations on *Cyrtanthus galpinii*, a species found in Piet Retief, Mpumalanga, South Africa questioned the fact that changes in land-use and landscape can possibly affect populations of grassland species (Craib, 2004).

## 6.2 CONCLUSION

With information generated by the current study, all the research questions in Chapter One were fulfilled. Distribution of *Cyrtanthus nutans*, although highly fragmented, was found to occur in the north-west of KZN, from Wasbank in the west, on the footslopes of the Noustrop Pass near Helpmekaar in the south, Tayside in the east and on the outskirts of Dundee town in the north, an area extending to 1 450km$^2$. Populations were fragmented, broken up by the various forms of land use. *Cyrtanthus nutans* plants were found predominantly along rail and road servitudes but also on the peripheral areas of agricultural grazing camps and urban areas.

The population density was addressed through the research carried out on the “snapshot” population figure. A total of 21 408 flowering plants were counted for the period 2013 until 2016. This did not include any leaves that had not developed flowers in the season they were counted. Taking into account the number of leaves in the experimental plots that exceeded the number of flowers at a ratio of almost 4:1, the population number most likely far exceeds the figure that was originally anticipated. Although the discovery of new sites of occurrence were fewer in the latter part of the study, most likely due to the limited range and fragmentation of the distribution, additional sites were still being located by Dundee residents in 2017, these however have not been verified.

Environmental factors that influenced the distribution of *Cyrtanthus nutans* were addressed through research on the abiotic factors. The climate of Dundee is variable, with contrasting years of drought and high annual rainfall years as well as frost occurrences in the winter months through to daytime temperatures of almost 40° C day in the summer months. The positive climatological factors that have shown to influence emergence in particular are late winter rain and a rise of just above 10% minimum relative humidity. Ideal climatological conditions for the stability of the population are based on an above mean annual rainfall and mean temperatures.

The majority of the *Cyrtanthus nutans* populations were found on the mid to lower slopes of the landscape on relatively flat grassveld areas with gradients of less than 10%, with no preference for a particular facing slope. Almost 98% of the flowering plants counted were in the altitude range of 1 100 to 1 300m a.m.s.l. Dolerite was the significant parent rock within the distribution range with soils that comprised of moderate levels of nitrogen and organic carbon yet low levels of phosphorus. Soils with low acidity levels were preferred but no preference for any particular soil texture. Flowering plants were predominantly located in two Bioresource Groups, namely: Sour Sandveld (BRG 14) and Moist Tall Grassveld (BRG 12).

The effects of fire and defoliation on the emergence and recruitment of seedlings of *Cyrtanthus nutans* was addressed in the research at the experimental plots and the documented presence or absence of fire and grazing at the sites of occurrence. *Cyrtanthus nutans* emerged readily in areas that were either burnt or comprised of a short grass sward providing little competition for emergence. The burning of sites after the initial spring rains was found to be detrimental to populations. Populations that had already emerged and then burnt after the initial spring rains indicated a steady reduction in population numbers over a short time period. Burning prior to the initial spring rain allowed for the removal of moribund material as well as allowing for an uninterrupted season for development until the seed dispersal stage.

The success or decline of *Cyrtanthus nutans* on all types of land use is subject to correct management practices. *Cyrtanthus nutans* has a preference for areas where land use provided minimal disturbance with only light large stock grazing and no human activities that changed the landscape such as compaction of soils through pedestrian and vehicular thoroughfares, development of land for agricultural crops or grading of road verges.

## 6.3 RECOMMENDATIONS

To summarize, the intention of the study was to provide custodians of *Cyrtanthus nutans* with an updated distribution pattern, to provide guidelines for management practices that will allow for the successful existence of this species and additionally, to provide scientists with information allowing for the update of current data and possible upgrade of conservation status of this species.

Abiotic conditions such as climatological factors cannot be manipulated to provide ideal conditions for *Cyrtanthus nutans*, however providing ideal conditions for the emergence and long term stability of a population through burning can be managed. Burning in August prior to the emergence of plants in September and prior to the initial spring rains reduces competition for emergence and allows for the development of the plants to the seed dispersal stage.

Biotic conditions in the form of herbivore and human activity can be manipulated through good management practices. Exclusion of grazing in *Cyrtanthus nutans* sites of occurrence for the period of growth and development (approximately two months in extent), will allow populations to colonise areas through seed dispersal for future recruitment. Limiting human activities for the two month period of flowering to reduce disturbances of populations and additionally preventing construction developments in areas where *Cyrtanthus nutans* sites of occurrence are located. The excessive clearing of road verges by provincial Departments of Transport needs to be addressed. In support of the statement made by McMaster (2009), legislation is clearly being contravened with no action taken to halt the wanton destruction of the many Red-Data species that occur on the road verges.

The unsuccessful relocation of the *Cyrtanthus nutans* plants as discussed in Chapter One, leads to supporting the statement made by Reid and Dyer (1984), that species which are becoming increasingly threatened require the intervention of horticultural cultivation.

In support of Scott-Shaw (1999) the monitoring of current sites and location of new sites needs to be undertaken on a regular basis, this in itself will indicate the long term stability of the *Cyrtanthus nutans* species.

# REFERENCES

Acocks, J. P. H. (1988). Veld types of South Africa. In: *Memoirs of the botanical survey of South Africa* (3rd ed.), Vol. 57.

Adamson, R. S. (1938). The vegetation of South Africa. British Empire Vegetation Committee, London.

Brown, D. & Le Maitre, D. (1990). Fire-lilies, the Firebirds of the Fynbos. *Veld & Flora*, *76*(1), 22.

Camp, K. G. T. (1999). A bioresource classification for KwaZulu-Natal, South Africa. M.Sc. dissertation, University of Natal, Pietermaritzburg.

Camp, K. G. T. (1999). In: HARDY, M.B. & Hurt, C.R. (ed). Veld in KwaZulu-Natal, Agricultural Production Guidelines for KwaZulu-Natal. KwaZulu-Natal Department of Agriculture, Pietermaritzburg.

Conservation of Agricultural Resources Act (1983). Act 43 of 1983. Government Printers, Pretoria, South Africa.

Craib, C. (2004). Will changing land-use patterns affect populations of the dainty fire lily, *Cyrtanthus galpinii* in Mpumalanga? *Veld & Flora,* 90(1), 24-25.

Department of Mineral and Energy Affairs. (1988). Geology of Dundee (2830). 1: 250 000 map series, Government Printer, Pretoria, South Africa.

Dlamini, T., Boycott, R., Culverwell, J., Dobson, L., Gama, R., Magagula, C., Magagula-Gumbi, L., Mahlaba, T., Masson, P. H., Monadiem, A., & Roques, K. G. (2001). Swaziland red data list for plants. Ministry of Agriculture/SABONET, Mbabane, Swaziland.

Dobson, A. J. (1983). An introduction to statistical modelling. Chapman & Hall, London.

Duncan, G. D. (2002). *Cyrtanthus*. *Plants of South Africa*. Kirstenbosch National Botanical Garden, South Africa.

Dyer, R. A. (1939). Description, classification and phylogeny. A review of the genus *Cyrtanthus. Herbertia*, *6*, 65-103.

Dyer, R. A. (1954). *Cyrtanthus. The Flowering Plants of Africa,* 30: t 1182.

Edwards, D. (1967). A plant ecology survey of the Tugela River basin, Natal. *Botanical Survey of Southern Africa. Memoir No. 36.* Natal Town and Regional Planning Reports. Volume 10: 15-52.

Environmental Conservation Act (1983). Act 73 of 1989. Government Printers, Pretoria, South Africa.

Ezemvelo KZN Wildlife. (2009). Topographical maps and GIS data. Accessed on the August 2010.

Ezemvelo KZN Wildlife. (2017). Our history. Website: http://www.kznwildlife.com /ezemvelo-history.com. Accessed on the 2 April 2017.

Fletcher, J. D., Shipley, L. A., McShea, W. J., & Shumway, D. L. (2001). Wildlife herbivory and rare plants: the effects of white-tailed deer, rodents, and insects on growth and survival of Turk's cap lily. *Biological Conservation*, *101*(2), 229-238.

GenStat® for Windows™ (18th Edition) – Introduction (Editor R.W. Payne), © 2015, VSN International, ISBN 1-904375-08-1. Website: http://www.genstat.co.uk.

Gordon, D. (2017). Personal Communication. Specialist Advisor (Agronomy) KwaZulu-Natal, Department of Agriculture and Environmental Affairs.

Gordon-Gray, K. D., & Wright, F. B. (1969). Cyrtanthus breviflorus and Cyrtanthus luteus (Amaryllidaceae): observations with particular reference to Natal populations. *South African Journal of Botany*, *35*, 35-62.

Hall, A. V., de Winter, M., de Winter, B., & van Oosterhout S. A. M. (1980). Threatened Plants of Southern Africa. South African National Science Programme Report 45, Council for Scientific and Industrial Research (CSIR), Pretoria.

Hardy, M. B., & Hurt, C. R. (1999). In: HARDY, M.B. & Hurt, C.R. (ed). pp 113, Veld in KwaZulu-Natal, Agricultural Production Guidelines for KwaZulu-Natal. KwaZulu-Natal Department of Agriculture, Pietermaritzburg.

Hilton-Taylor, C. (1996). *Red data list of southern African plants*. Strelitzia 4. National Botanical Institute.

Howard, T. G., & Goldberg, D. E. (2001). Competitive response hierarchies for germination, growth, and survival and their influence on abundance. *Ecology*, *82*(4), 979-990.

Huggett, R. J. (2004). Fundamentals of biogeography. (2nd Ed.). Oxfordshire: Routledge.

IUCN. (2012). IUCN Red list categories and criteria: Version 3.1. Second Edition. Gland, Switzerland and Cambridge, UK.

IUCN. (2016). The IUCN red list of threatened species. Version 2016-3. Hyperlink: [http://www.iucnredlist.org]. Accessed on 2 January 2017.

Keeley, J. E. (1993). Smoke-induced flowering in the fire-lily Cyrtanthus ventricosus. *South African Journal of Botany*, *59*(6), 638.

Le Maitre, D. C., & Brown, P. J. (1992). Life cycles and fire-stimulated flowering in geophytes. In *Fire in South African mountain fynbos* (pp. 145-160). Springer Berlin Heidelberg.

Low, A. B., & Rebelo, A. G. (1996). Vegetation of South Africa, Lesotho and Swaziland. A companion to the vegetation map of South Africa, Lesotho and Swaziland. *Pretoria: Department of Environmental Affairs and Tourism*.

Macdonald, I. A. W. (1989). Man's role in changing the face of southern Africa. *Biotic Diversity in Southern Africa: Concepts and Conservation.* Oxford University Press, Cape Town.

Manson, A. D., Miles, N., & Farina, M. P. W. (2012). The Cedara computerized fertilizer advisory service (FertRec): Explanatory notes and crop and soil norms.

KwaZulu-Natal Department of Agriculture and Environmental Affairs, Pietermaritzburg, South Africa.

Manson, A. D., & Roberts, V. G. (2001). Analytical methods used by the soil fertility and analytical services section. Republic of South Africa, Pietermaritzburg.

Maron, J. L., & Crone, E. (2006). Herbivory: effects on plant abundance, distribution and population growth. *Proceedings of the Royal Society of London B: Biological Sciences*, *273*(1601), 2575-2584.

McMaster, C. (2004). Cyrtanthus macmasteri. *Veld Flora (Kirstenbosch)*, *90*(1), 20-23.

McMaster, C. (2007). The farmer's role in biodiversity conservation. *Farmer's Weekly*, 21 September: p 26-27.

McMaster, C. (2008). Not only diversity makes *Cyrtanthus* exceptional. *Farmer's Weekly*, 11 January: p 38-39.

McMaster, C. (2009). Road reserves and breaking the law. *Farmer's Weekly*, 23 January, 2009.

McNeil, G. (1967). A brief introduction to *Cyrtanthus. Journal of the Royal Horticultural Society:* XCII (4):180-183.

Mitchell, J. (2012). Personal Communication. Environmental Consultant, Mitchell & Associates, Dundee, KwaZulu-Natal.

Mucina, L., & Rutherford, M. C. (2006). The vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19, South African National Biodiversity Institute, Pretoria. *Memoirs of the Botanical Survey of South Africa*.

Natal Parks Board. (1969). Nature Conservation Ordinance no. 15 of 1974.

National Environmental Management Act (NEMA) (1998) Act 107 of 1998. Government Printers, Pretoria, South Africa.

National Environmental Management: Biodiversity Act (NEMBA) (2004) Act 10 of 2004. Government Gazette 32090, 3 April 2009. Government Printers, Pretoria, South Africa.

Parliament of the Province of KwaZulu-Natal. The Kwazulu-Natal Nature Conservation Management Act 29 of 1992.

Parliament of the Province of KwaZulu-Natal. The Kwazulu-Natal Nature Conservation Management Act 9 of 1997.

Parliament of the Province of KwaZulu-Natal. The KwaZulu-Natal Nature Conservation Amendment Act 5 of 1999 and the KwaZulu-Natal Nature Conservation Amendment Act 7 of 1999.

Parliament of the Province of KwaZulu-Natal. The KwaZulu-Natal Environmental, Biodiversity and Protected Areas Management Bill, 2014.

Pentz, J. A. (1938). The value of botanical survey and the mapping of vegetation as applied to farming systems in South Africa. *Memoirs of the Botanical Survey of South Africa*. no. 19.

Phillips, J. F. V. (1973). *The agricultural and related development of the Tugela Basin and its influent surrounds: a study in subtropical Africa* (Vol. 19). Natal Town and Regional Planning Commission.

Pole-Evans, I. P. (1936). *A vegetation map of South Africa*. Government Printer, South Africa.

Raimondo, D., Staden, L. V., Foden, W., Victor, J. E., Helme, N. A., Turner, R. C., Kamundi, D.A., & Manyama, P. A. (2009). *Red list of South African plants. Strelitzia 25.* South African National Biodiversity Institute.

Reid, C., & Dyer, R. A. (1984). A review of the southern African species of Cyrtanthus. *La Jolla: California, American Plant Life Society. iv, 68p.-illus., col. illus., maps, keys. En Icones, Maps. Geog*, *5*.

Republic of South Africa. (1996). Constitution of the Republic of South Africa, Act 108 of 1996. *Government Gazette*, *378*.

Roskov, Y., Abucay, L., Orrell, T., Nicolson, D., Bailly, N., Kirk, P.M., Bourgoin, T., De Walt, R.E., Decock, W., De Wever, A., Van Nieukerken, E., Zarucchi, J. & Penev, L., eds. (2017). Species 2000 & ITIS Catalogue of Life, 2017 Annual Checklist. Digital resource at www.catalogueoflife.org/annual-checklist/2017. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-884X.

SANBI. (2012). South African National Biodiversity Institute. Hyperlink: [www. redlist.sanbi.org/genus.php?genus=2088]. Accessed on 4 January 2017.

SANBI. (2017). Statistics: Red List of South African Plants version 2017.1. Hyperlink: [www.redlist.sanbi.org]. Accessed on 4 January 2017.

Scott Shaw, C. R. (1999). Rare and threatened plants of KwaZulu-Natal and neighbouring regions. Scientific Services Directorate, KwaZulu-Natal Nature Conservation Service, Pietermaritzburg.

Scott-Shaw, C. R. (2011). Personal communication. Ecologist: KwaZulu-Natal Nature Conservation Services, Pietermaritzburg.

Scott-Shaw, C. R., Snijman, D. A. & Raimondo, D. (2007). *Cyrtanthus nutans.* R.A.Dyer. National Assessment: Red List of South African Plants. V2011.1. Accessed on 4 April, 2016.

Smith, J. M. B & Camp, K. G. T. (1999). Planning a veld management programme for a farm. In: HARDY, M.B. & Hurt, C.R. (ed). pp 6, Veld in KwaZulu-Natal, Agricultural Production Guidelines for KwaZulu-Natal. KwaZulu-Natal Department of Agriculture, Pietermaritzburg.

Snijman, D. A. (2003). A new Cyrtanthus species (Amaryllidaceae: Cyrtantheae) endemic to the Albany Centre, Eastern Cape, South Africa. *Bothalia*, *33*(2), 145-147.

Soil Classification Working Group. (1991). *Soil Classification: A Taxonomic System for South Africa: A Report on a Research Project Conducted Under the Auspices of the Soil and Irrigation Research Institute*. Department of Agricultural Development.

Statistics South Africa. (2016). *Mid-year population estimates: 2016.* Report No. P0302. Hyperlink: [www.statssa.gov.za/publications/P0302/P03022016.pdf] Accessed 3 February 2017.

Trollope, W. S. (1982). Ecological effects of fire in South African savannas. In: Huntley BJ, Walker BH (eds.) Ecology of Tropical Savannas. Springer-Verlag, Berlin, pp 92–306.

Van der Linde, M. (ed.) (2008). *Compendium of South African Environmental Legislation.* Pretoria: PULP.

Van Zyl, E. A. (2017). Personal Communication. Specialist Advisor (Grass and Forages Science), KwaZulu-Natal, Department of Agriculture and Environmental Affairs.

ORIGINAL

EZEMVELO KZN WILDLIFE

Conservation, Partnerships & Ecotourism

# ORDINARY PERMIT

Fee: R 0.00

Receipt No: 1835/2014

Permit No: OP 2091/2014

Contact: Miss S.M. Hughes

This permit is issued in pursuance of the provisions of the Nature Conservation Ordinance No 15 of 1974 , Chapter 11 and the Regulations framed thereunder.

The permit is issued to:

**ID Number: 6510250027085**

**Mrs Lynne Ruddle**
**PO Box 743**
**Dundee**
**3000**

**Residential Address**
**95 Mckenzie Street**
**Dundee**
**3000**

**Conservation District:** Dundee

**Province:** KwaZulu-Natal

In the capacity of Collector

To Collect the following species of Plants

INDIGENOUS PLANTS

3 (Three) individuals per species per locality may be collected throughout KwaZulu-Natal EXCLUDING KZN Wildlife protected areas but including the following protected areas: Ncandu Forest Reserve, Spioenkop Dam, Weenen Game Reserve, Chelmsford, Wagendrift, Moor Park, Isandlwana and Tugela Drift.

***Please read the Terms and Conditions under which this Permit is issued***

ISSUED at PIETERMARITZBURG, KwaZulu-Natal, on 30 April 2014

for CHIEF EXECUTIVE

Permit Holder

EZEMVELO KZN WILDLIFE PERMITS OFFICE
PO Box 13053, Cascades, 3202, Pietermaritzburg, KwaZulu-Natal.
Tel +27 33 845 1320 / 1324. Fax: +27 33 845 1747. Fax to Email: 086 529 3320
Email: permits@kznwildlife.com. Website: www.kznwildlife.com

ORIGINAL

EZEMVELO KZN WILDLIFE

Conservation, Partnerships & Ecotourism

## TERMS AND CONDITIONS UNDER WHICH THIS PERMIT IS ISSUED

1. It is valid only:

   (i) from : 30 April 2014
   to : 31 December 2014

   (ii) in the original

   (iii) if all **3** pages are signed by the permit holder named above

   (iv) to the permit holder named above

2. By signing the permit or licence the holder accepts, and agrees to comply with the conditions under which it is issued.

3. Permit shall be carried by holder, or the specified nominees, at all times during use.

4. Outside of E KZN Wildlife areas, use of this permit is subject to landowner's or controlling authority's written permission.

5. Prior to collecting in areas under the control of the E KZN Wildlife the holders shall contact the Officer-in-Charge of the area at least 48 (Forty-eight) hours before commencing, and shall comply with any conditions which the Officer may impose at his discretion.

6. At least one representative specimen (preferably at least one male and one female) of each species collected from each locality must be lodged with a recognised South African museum/herbarium. Holotype specimens, and half the number of paratype specimens, of any new species MUST BE DEPOSITED with a recognised South African museum/herbarium, and may only leave South Africa on a loan basis. These specimens are to be deposited in the SA museums within a year of publishing the description of the new species. The holder shall provide the Chief Executive Officer, KZNNCS with the name of the museum at which the specimens have been lodged, and the accession number of each specimen. This condition relates to unavoidable by-catch of non-target organisms as well.

7. A copy or copies of any publication arising from the authority herein contained will be made available to E KZN Wildlife.

8. (i) Reserving accommodation within E KZNWildlife areas is entirely the responsibility of the permit holder. Booking is obtainable at the Central Booking Office, Telephone 033 8451000.(ii) Any assistance required from Board staff will be subject to other demands on the Officer's time and must be arranged in advance with him/her.

9. Failure to comply with the terms and conditions of this permit could result in the cancellation thereof and jeopardise the re-issue of a permit in the future.

***Please read the Terms and Conditions under which this Permit is issued***

ISSUED at PIETERMARITZBURG, KwaZulu-Natal, on 30 April 2014

for CHIEF EXECUTIVE | Permit Holder

EZEMVELO KZN WILDLIFE PERMITS OFFICE
PO Box 13053, Cascades, 3202, Pietermaritzburg, KwaZulu-Natal.
Tel +27 33 845 1320 / 1324. Fax: +27 33 845 1747. Fax to Email: 086 529 3320
Email: permits@kznwildlife.com. Website: www.kznwildlife.com

ORIGINAL

EZEMVELO KZN WILDLIFE

Conservation, Partnerships & Ecotourism

10. Holders shall provide the Chief Executive, with a named list of every specimen collected (including the class, order, family, gender and age), the geographical co-ordinates (to seconds accuracy) of each collection locality and dates of collection, as laid out in the following table. A Global Positioning System with the WGS84 Datum should be used wherever possible to determine the geographical co-ordinates of the collection sites; please state the method used.

11. SPECIMEN (museum Accession) - COLLECTION DATE (ddmmyy) - SPECIES - LOCALITY - LATITUDE (Seconds Accuracy) - LONGITUDE (Seconds Accuracy). Holders are requested to provide additional information, such as the habitat in which each specimen was collected and abundance or relative abundance data (providing standardised sampling methods are used) with the list.

12. No collecting is permitted in the wilderness areas within the Protected Area. For confirmation of boundaries of the wilderness area contact the Officer in Charge.

13. No collecting of any plants listed in the Threatened or Protected Species Regulations is permitted.

***Please read the Terms and Conditions under which this Permit is issued***

ISSUED at PIETERMARITZBURG, KwaZulu-Natal, on 30 April 2014

for CHIEF EXECUTIVE

Permit Holder

ORIGINAL

EZEMVELO KZN WILDLIFE

Conservation, Partnerships & Ecotourism

# ORDINARY PERMIT

Fee: R 0.00

Receipt No: 5307/2014

Permit No: OP 5501/2014

Contact: Miss S.M. Hughes

This permit is issued in pursuance of the provisions of the Nature Conservation Ordinance No 15 of 1974 , Chapter 11 and the Regulations framed thereunder.

The permit is issued to:

**ID Number: 6510250027085**

**Mrs Lynne Ruddle**
**PO Box 743**
**Dundee**
**3000**

**Residential Address**
**95 Mckenzie Street**
**Dundee**
**3000**

In the capacity of Collector

To Collect the following species of Plants

INDIGENOUS PLANTS

3 (Three) Specimens per species per protected area EXCLUDING TOPS may be collected throughout KwaZulu-Natal EXCLUDING KZN Wildlife protected areas but including the following protected areas: Ncandu Forest Reserve, Spioenkop Dam, Weenen Game Reserve, Chelmsford, Wagendrift, Moor Park, Isandlwana and Tugela Drift.

***Please read the Terms and Conditions under which this Permit is issued***

ISSUED at PIETERMARITZBURG, KwaZulu-Natal, on 23 December 2014

for CHIEF EXECUTIVE

Permit Holder

EZEMVELO KZN WILDLIFE PERMITS OFFICE
PO Box 13053, Cascades, 3202, Pietermaritzburg, KwaZulu-Natal.
Tel +27 33 845 1320 / 1324. Fax: +27 33 845 1747. Fax to Email: 086 529 3320
Email: permits@kznwildlife.com. Website: www.kznwildlife.com

ORIGINAL

EZEMVELO KZN WILDLIFE

Conservation, Partnerships & Ecotourism

# TERMS AND CONDITIONS UNDER WHICH THIS PERMIT IS ISSUED

1. It is valid only:

   (i) from : 01 January 2015
   to : 31 December 2015

   (ii) in the original

   (iii) if all **3** pages are signed by the permit holder named above

   (iv) to the permit holder named above

2. By signing the permit or licence the holder accepts, and agrees to comply with the conditions under which it is issued.

3. Permit shall be carried by holder, or the specified nominees, at all times during use.

4. Outside of E KZN Wildlife areas, use of this permit is subject to landowner's or controlling authority's written permission.

5. Prior to collecting in areas under the control of the E KZN Wildlife the holders shall contact the Officer-in-Charge of the area at least 48 (Forty-eight) hours before commencing, and shall comply with any conditions which the Officer may impose at his discretion.

6. At least one representative specimen (preferably at least one male and one female) of each species collected from each locality must be lodged with a recognised South African museum/herbarium. Holotype specimens, and half the number of paratype specimens, of any new species MUST BE DEPOSITED with a recognised South African museum/herbarium, and may only leave South Africa on a loan basis. These specimens are to be deposited in the SA museums within a year of publishing the description of the new species. The holder shall provide the Chief Executive Officer, KZNNCS with the name of the museum at which the specimens have been lodged, and the accession number of each specimen. This condition relates to unavoidable by-catch of non-target organisms as well.

7. A copy or copies of any publication arising from the authority herein contained will be made available to E KZN Wildlife.

8. (i) Reserving accommodation within E KZNWildlife areas is entirely the responsibility of the permit holder. Booking is obtainable at the Central Booking Office, Telephone 033 8451000.(ii) Any assistance required from Board staff will be subject to other demands on the Officer's time and must be arranged in advance with him/her.

9. Failure to comply with the terms and conditions of this permit could result in the cancellation thereof and jeopardise the re-issue of a permit in the future.

***Please read the Terms and Conditions under which this Permit is issued***

ISSUED at PIETERMARITZBURG, KwaZulu-Natal, on 23 December 2014

for CHIEF EXECUTIVE

Permit Holder

EZEMVELO KZN WILDLIFE PERMITS OFFICE
PO Box 13053, Cascades, 3202, Pietermaritzburg, KwaZulu-Natal.
Tel +27 33 845 1320 / 1324. Fax: +27 33 845 1747. Fax to Email: 086 529 3320
Email: permits@kznwildlife.com. Website: www.kznwildlife.com

ORIGINAL

EZEMVELO KZN WILDLIFE

Conservation, Partnerships & Ecotourism

10. Holders shall provide the Chief Executive, with a named list of every specimen collected (including the class, order, family, gender and age), the geographical co-ordinates (to seconds accuracy) of each collection locality and dates of collection, as laid out in the following table. A Global Positioning System with the WGS84 Datum should be used wherever possible to determine the geographical co-ordinates of the collection sites; please state the method used.

11. SPECIMEN (museum Accession) - COLLECTION DATE (ddmmyy) - SPECIES - LOCALITY - LATITUDE (Seconds Accuracy) - LONGITUDE (Seconds Accuracy). Holders are requested to provide additional information, such as the habitat in which each specimen was collected and abundance or relative abundance data (providing standardised sampling methods are used) with the list.

12. No collecting is permitted in the wilderness areas within the Protected Area. For confirmation of boundaries of the wilderness area contact the Officer in Charge.

***Please read the Terms and Conditions under which this Permit is issued***

ISSUED at PIETERMARITZBURG, KwaZulu-Natal, on 23 December 2014

for CHIEF EXECUTIVE

Permit Holder

ORIGINAL

EZEMVELO KZN WILDLIFE

Conservation, Partnerships & Ecotourism

# ORDINARY PERMIT

| | | | |
|---|---|---|---|
| Fee: | R 0.00 | Permit No: | OP 5401/2015 |
| Receipt No: | 5305/2015 | Contact: | Miss S.M. Hughes |

This permit is issued in pursuance of the provisions of the Nature Conservation Ordinance No 15 of 1974 , Chapter 11 and the Regulations framed thereunder.

The permit is issued to:

**ID Number: 6510250027085**

**Mrs Lynne Ruddle**
**PO Box 743**
**Dundee**
**3000**

**Residential Address**
**95 Mckenzie Street**
**Dundee**
**3000**

In the capacity of Collector
To Collect the following species of Plants

INDIGENOUS PLANTS

3 (Three) Specimens per species per protected area EXCLUDING TOPS may be collected throughout KwaZulu-Natal EXCLUDING KZN Wildlife protected areas but including the following protected areas: Ncandu Forest Reserve, Spioenkop Dam, Weenen Game Reserve, Chelmsford, Wagendrift, Moor Park, Isandlwana and Tugela Drift.

***Please read the Terms and Conditions under which this Permit is issued***

ISSUED at PIETERMARITZBURG, KwaZulu-Natal, on 23 December 2015

for CHIEF EXECUTIVE

Permit Holder

EZEMVELO KZN WILDLIFE PERMITS OFFICE
PO Box 13053, Cascades, 3202, Pietermaritzburg, KwaZulu-Natal.
Tel +27 33 845 1320 / 1324. Fax: +27 33 845 1747. Fax to Email: 086 529 3320
Email: permits@kznwildlife.com. Website: www.kznwildlife.com

ORIGINAL

EZEMVELO KZN WILDLIFE

Conservation, Partnerships & Ecotourism

## TERMS AND CONDITIONS UNDER WHICH THIS PERMIT IS ISSUED

1. It is valid only:

   (i) from : 01 January 2016
   to : 31 December 2016

   (ii) in the original

   (iii) if all **3** pages are signed by the permit holder named above

   (iv) to the permit holder named above

2. By signing the permit or licence the holder accepts, and agrees to comply with the conditions under which it is issued.

3. Permit shall be carried by holder, or the specified nominees, at all times during use.

4. Outside of E KZN Wildlife areas, use of this permit is subject to landowner's or controlling authority's written permission.

5. Prior to collecting in areas under the control of the E KZN Wildlife the holders shall contact the Officer-in-Charge of the area at least 48 (Forty-eight) hours before commencing, and shall comply with any conditions which the Officer may impose at his discretion.

6. At least one representative specimen (preferably at least one male and one female) of each species collected from each locality must be lodged with a recognised South African museum/herbarium. Holotype specimens, and half the number of paratype specimens, of any new species MUST BE DEPOSITED with a recognised South African museum/herbarium, and may only leave South Africa on a loan basis. These specimens are to be deposited in the SA museums within a year of publishing the description of the new species. The holder shall provide the Chief Executive Officer, KZNNCS with the name of the museum at which the specimens have been lodged, and the accession number of each specimen. This condition relates to unavoidable by-catch of non-target organisms as well.

7. A copy or copies of any publication arising from the authority herein contained will be made available to E KZN Wildlife.

8. (i) Reserving accommodation within E KZNWildlife areas is entirely the responsibility of the permit holder. Booking is obtainable at the Central Booking Office, Telephone 033 8451000.(ii) Any assistance required from Board staff will be subject to other demands on the Officer's time and must be arranged in advance with him/her.

9. Failure to comply with the terms and conditions of this permit could result in the cancellation thereof and jeopardise the re-issue of a permit in the future.

***Please read the Terms and Conditions under which this Permit is issued***

ISSUED at PIETERMARITZBURG, KwaZulu-Natal, on 23 December 2015

for CHIEF EXECUTIVE

Permit Holder

EZEMVELO KZN WILDLIFE PERMITS OFFICE
PO Box 13053, Cascades, 3202, Pietermaritzburg, KwaZulu-Natal.
Tel +27 33 845 1320 / 1324. Fax: +27 33 845 1747. Fax to Email: 086 529 3320
Email: permits@kznwildlife.com. Website: www.kznwildlife.com

ORIGINAL

EZEMVELO KZN WILDLIFE

Conservation, Partnerships & Ecotourism

10. Holders shall provide the Chief Executive, with a named list of every specimen collected (including the class, order, family, gender and age), the geographical co-ordinates (to seconds accuracy) of each collection locality and dates of collection, as laid out in the following table. A Global Positioning System with the WGS84 Datum should be used wherever possible to determine the geographical co-ordinates of the collection sites; please state the method used.

11. SPECIMEN - COLLECTION DATE - SPECIES - LOCALITY - LATITUDE - LONGITUDE (museum Accession) (ddmmyy) (Seconds Accuracy) (Seconds Accuracy).
Holders are requested to provide additional information, such as the habitat in which each specimen was collected and abundance or relative abundance data (providing standardised sampling methods are used) with the list.

12. No collecting is permitted in the wilderness areas within the Protected Area. For confirmation of boundaries of the wilderness area contact the Officer in Charge.

***Please read the Terms and Conditions under which this Permit is issued***

ISSUED at PIETERMARITZBURG, KwaZulu-Natal, on 23 December 2015

for CHIEF EXECUTIVE

Permit Holder

EZEMVELO KZN WILDLIFE PERMITS OFFICE
PO Box 13053, Cascades, 3202, Pietermaritzburg, KwaZulu-Natal.
Tel +27 33 845 1320 / 1324. Fax: +27 33 845 1747. Fax to Email: 086 529 3320
Email: permits@kznwildlife.com. Website: www.kznwildlife.com

UNISA university of south africa

## CAES RESEARCH ETHICS REVIEW COMMITTEE

Date: 10/11/2014

Ref #: **2014/CAES/148**
Name of applicant: **Ms LM Ruddle**
Student #: **40549925**

Dear Ms Ruddle,

**Decision: Ethics Approval**

---

**Proposal:** Ecological characterisation and effects of fire and grazing on *Cyrtanthus nutans* (R.A.Dyer) in North Western Kwazulu-Natal, South Africa

**Supervisor:** Dr E Van Zyl

**Qualification:** Postgraduate degree

---

Thank you for the application for research ethics clearance by the CAES Research Ethics Review Committee for the above mentioned research. Final approval is granted for the duration of the project.

Please consider point 4 below for further action.

*The application was reviewed in compliance with the Unisa Policy on Research Ethics by the CAES Research Ethics Review Committee on 06 November 2014.*

*The proposed research may now commence with the proviso that:*

1) *The researcher/s will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.*
2) *Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study, as well as changes in the methodology, should be communicated in writing to the CAES Research Ethics Review Committee. An amended application could be requested if there are substantial changes from the existing proposal, especially if those changes affect any of the study-related risks for the research participants.*
3) *The researcher will ensure that the research project adheres to any applicable*

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

*national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study.*

4) *The submitted permit expires on 31 December 2014, and is also not signed by the permit holder. The researcher will have to apply for a new permit for 2015 – this must be submitted to the Committee once it is obtained. The researcher is also requested to ensure that a signed version is submitted.*

*Note:*

*The reference number [top right corner of this communiqué] should be clearly indicated on all forms of communication [e.g. Webmail, E-mail messages, letters] with the intended research participants, as well as with the CAES RERC.*

Kind regards,

Signature
CAES RERC Chair: Prof EL Kempen

Signature
CAES Executive Dean: Prof MJ Linington

PLEASE NOTE PROVISIONS.



University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

# *DRAFSTAP BOERDERY CC*

**CK 2006/015248/23 VAT 4050226192**

**P.O. Box 281**
**Dundee**
**3000**
**034 21 82443**
**034 21 82951**
**086 609 9196**
**082 654 9944**
**hein@trustnet.co.za**

---

15/10/2014

HEIL DIE LESER

Hiermee toestemming aan Lynne Ruddle om n studie uit te voer op blomme Op die plaas Lerryn, Dundee, en hiermee word sy ook gevrywaar van enige skade wat dit mag mee bring.

DIE UWE

HS POTGIETER

HS Potgieter JE Potgieter HH Davie

| BIORESOURCE GROUP 12: MOIST TALL GRASSVELD | | | | | | | |
|---|---|---|---|---|---|---|---|
| **VELD CONDITION** | | | | | | | |
| **Aerodrome** | **S28.186716** | **E30.217587** | | | | | |
| **Group** | **Species:** | **Grazing Value** | **Benchmark** | | **Site 1** | | |
| | | | **%** | **Score** | **Count** | **%** | **Score** |
| **Increaser I** | *Cymbopogon excavatus* | 1 | 1 | 1 | | 0.0 | 0.0 |
| | *Setaria nigrorostis* | 5 | 1 | 5 | 1 | 2.1 | 10.6 |
| | *Tristachya leucothrix* | 9 | 17 | 153 | 20 | 42.6 | 383.0 |
| | | **Total** | **19** | **159** | **21** | **44.7** | **393.6** |
| **Decreaser** | *Brachiaria serrata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Diheteropogon amplectens* | 8 | 1 | 8 | | 0.0 | 0.0 |
| | *Melenis nerviglumis* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Themeda triandra* | 10 | 50 | 500 | 7 | 14.9 | 148.9 |
| | *Andropogon appendiculatus* | 5 | | 0 | 1 | 2.1 | 10.6 |
| | | **Total** | **53** | **513** | **8** | **17.0** | **159.6** |
| **Increaser IIa** | *Eragrostis capensis* | 2 | 5 | 10 | 2 | 4.3 | 8.5 |
| | *Heteropogon contortus* | 6 | 4 | 24 | 1 | 2.1 | 12.8 |
| | | **Total** | **9** | **34** | **3** | **6.4** | **21.3** |
| **Increaser IIb** | *Eragrostis curvula* | 5 | 1 | 5 | | 0.0 | 0.0 |
| | *Eragrostis plana* | 3 | 1 | 3 | 1 | 2.1 | 6.4 |
| | *Eragrostis racemosa* | 2 | 2 | 4 | | 0.0 | 0.0 |
| | *Hyparrhenia hirta* | 6 | 2 | 12 | | 0.0 | 0.0 |
| | *Sporobolus africanus* | 3 | 2 | 6 | 6 | 12.8 | 38.3 |
| | *Setaria flabellata* | 2 | 3 | 6 | | 0.0 | 0.0 |
| | *Eragrostis chloromelas* | 0 | | | 1 | 2.1 | 0.0 |
| | | **Total** | **11** | **36** | **8** | **17.0** | **44.7** |
| **Increaser IIc** | *Aristida congesta* | 0 | 1 | 0 | | 0.0 | 0.0 |
| | Forbs | 0 | 4 | 0 | | 0.0 | 0.0 |
| | Sedges | 0 | 3 | 0 | | 0.0 | 0.0 |
| | *Microloa caffra* | 0 | 1 | 0 | 1 | 2.1 | 0.0 |
| | *Brachiaria eruciformes* | 1 | | 0 | 2 | 4.3 | 4.3 |
| | *Paspalum notatum* | 3 | | 0 | | 0.0 | 0.0 |
| | | **Total** | **9** | **0** | **3** | **6.4** | **4.3** |
| **Increaser III** | *Elionurus muticus* | 0 | | 0 | 3 | 6.4 | 0.0 |
| | *Aristida junciformes* | 0 | | 0 | 1 | 2.1 | 0.0 |
| | | **Total** | **0** | **0** | **4** | **8.5** | **0.0** |
| | | **GRAND TOTAL** | **101** | **742** | **47** | **100** | **623.4** |
| | | **SCORE** | | | | **84.0** | |

**GRAZING CAPACITY**

| | | | | |
|---|---|---|---|---|
| **Rainfall** | Mean Annual Rainfall | 750 | Effective rainfall | 600 |
| **Production** | Veld condition score | 0.840 | Production /mm rain | 4.201 |
| | Woody species impact | 1.00 | Production / ha | 2520.50 |
| | Accessibilty factor | 1.00 | | |
| **Utilization** | Utilizable production | 1260.25 | Grazing period | 365 |
| **Grazing Capacity** | Domesticated livestock | 3 | Conservation | 4 |

| BIORESOURCE GROUP 12: MOIST TALL GRASSVELD | | | | | | | |
|---|---|---|---|---|---|---|---|
| VELD CONDITION | | | | | | | |
| **Meer** | **S28.161668** | **E30.217237** | | | | | |
| **Group** | **Species:** | **Grazing Value** | **Benchmark** | | **Site 1** | | |
| | | | **%** | **Score** | **Count** | **%** | **Score** |
| **Increaser I** | *Cymbopogon excavatus* | 1 | 1 | 1 | 1 | 2.0 | 2.0 |
| | *Setaria nigrorostis* | 5 | 1 | 5 | 2 | 3.9 | 19.6 |
| | *Tristachya leucothrix* | 9 | 17 | 153 | | 0.0 | 0.0 |
| | *Digitaria tricholaenoides* | 6 | | 0 | 5 | 9.8 | 58.8 |
| | *Trachypogon spicatus* | 3 | | 0 | 1 | 2.0 | 5.9 |
| | *Hyparrenia dregeana* | 5 | | 0 | 1 | 2.0 | 9.8 |
| | | **Total** | **19** | **159** | **10** | **19.6** | **96.1** |
| **Decreaser** | *Brachiaria serrata* | 3 | 1 | 3 | 1 | 2.0 | 5.9 |
| | *Diheteropogon amplectens* | 8 | 1 | 8 | 3 | 5.9 | 47.1 |
| | *Melenis nerviglumis* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Themeda triandra* | 10 | 50 | 500 | 32 | 62.7 | 627.5 |
| | | **Total** | **53** | **513** | **36** | **70.6** | **680.4** |
| **Increaser IIa** | *Eragrostis capensis* | 2 | 5 | 10 | | 0.0 | 0.0 |
| | *Heteropogon contortus* | 6 | 4 | 24 | 1 | 2.0 | 11.8 |
| | | **Total** | **9** | **34** | **1** | **2.0** | **11.8** |
| **Increaser IIb** | *Eragrostis curvula* | 5 | 1 | 5 | 2 | 3.9 | 19.6 |
| | *Eragrostis plana* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Eragrostis racemosa* | 2 | 2 | 4 | | 0.0 | 0.0 |
| | *Hyparrhenia hirta* | 6 | 2 | 12 | 1 | 2.0 | 11.8 |
| | *Sporobolus africanus* | 3 | 2 | 6 | | 0.0 | 0.0 |
| | *Setaria flabellata* | 2 | 3 | 6 | | 0.0 | 0.0 |
| | *Eragrostis chloromelas* | 0 | | | | 0.0 | 0.0 |
| | | **Total** | **11** | **36** | **3** | **5.9** | **31.4** |
| **Increaser IIc** | *Aristida congesta* | 0 | 1 | 0 | | 0.0 | 0.0 |
| | Forbs | 0 | 4 | 0 | | 0.0 | 0.0 |
| | Sedges | 0 | 3 | 0 | | 0.0 | 0.0 |
| | *Microloa caffra* | 0 | 1 | 0 | | 0.0 | 0.0 |
| | *Cynodon dactylon* | 3 | | 0 | | 0.0 | 0.0 |
| | *Paspalum notatum* | 3 | | 0 | | 0.0 | 0.0 |
| | | **Total** | **9** | **0** | **0** | **0.0** | **0.0** |
| **Increaser III** | *Elionurus muticus* | 0 | | 0 | 1 | 2.0 | 0.0 |
| | | **Total** | **0** | **0** | **1** | **2.0** | **0.0** |
| | | **GRAND TOTAL** | **101** | **742** | **51** | **100** | **819.6** |
| | | **SCORE** | | | | **110.5** | |

| GRAZING CAPACITY | | | | |
|---|---|---|---|---|
| **Rainfall** | Mean Annual Rainfall | 750 | Effective rainfall | 600 |
| **Production** | Veld condition score | 1.105 | Production /mm rain | 5.523 |
| | Woody species impact | 1.00 | Production / ha | 3313.78 |
| | Accessibilty factor | 1.00 | | |
| **Utilization** | Utilizable production | 1656.89 | Grazing period | 365 |
| **Grazing Capacity** | Domesticated livestock | 2 | Conservation | 3 |

| BIORESOURCE GROUP 12: MOIST TALL GRASSVELD | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | VELD CONDITION | | | | | |
| Showgrounds | S28.160318 | E30.226347 | | | | | |
| Group | Species: | Grazing Value | Benchmark | | Site 1 | | |
| | | | % | Score | Count | % | Score |
| Increaser I | *Cymbopogon excavatus* | 1 | 1 | 1 | 1 | 1.9 | 1.9 |
| | *Setaria nigrorostis* | 5 | 1 | 5 | | 0.0 | 0.0 |
| | *Tristachya leucothrix* | 9 | 17 | 153 | 1 | 1.9 | 17.3 |
| | | **Total** | **19** | **159** | **2** | **3.8** | **19.2** |
| Decreaser | *Brachiaria serrata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Diheteropogon amplectens* | 8 | 1 | 8 | | 0.0 | 0.0 |
| | *Melenis nerviglumis* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Themeda triandra* | 10 | 50 | 500 | 2 | 3.8 | 38.5 |
| | | **Total** | **53** | **513** | **2** | **3.8** | **38.5** |
| Increaser IIa | *Eragrostis capensis* | 2 | 5 | 10 | | 0.0 | 0.0 |
| | *Heteropogon contortus* | 6 | 4 | 24 | | 0.0 | 0.0 |
| | | **Total** | **9** | **34** | **0** | **0.0** | **0.0** |
| Increaser IIb | *Eragrostis curvula* | 5 | 1 | 5 | 9 | 17.3 | 86.5 |
| | *Eragrostis plana* | 3 | 1 | 3 | 8 | 15.4 | 46.2 |
| | *Eragrostis racemosa* | 2 | 2 | 4 | | 0.0 | 0.0 |
| | *Hyparrhenia hirta* | 6 | 2 | 12 | | 0.0 | 0.0 |
| | *Sporobolus africanus* | 3 | 2 | 6 | 2 | 3.8 | 11.5 |
| | *Setaria flabellata* | 2 | 3 | 6 | | 0.0 | 0.0 |
| | *Eragrostis chloromelas* | 0 | | | 6 | 11.5 | 0.0 |
| | | **Total** | **11** | **36** | **25** | **48.1** | **144.2** |
| Increaser IIc | *Aristida congesta* | 0 | 1 | 0 | 2 | 3.8 | 0.0 |
| | Forbs | 0 | 4 | 0 | | 0.0 | 0.0 |
| | Sedges | 0 | 3 | 0 | | 0.0 | 0.0 |
| | *Microloa caffra* | 0 | 1 | 0 | 3 | 5.8 | 0.0 |
| | *Cynodon dactylon* | 3 | | 0 | 15 | 28.8 | 86.5 |
| | *Paspalum notatum* | 3 | | 0 | 2 | 3.8 | 11.5 |
| | | **Total** | **9** | **0** | **22** | **42.3** | **98.1** |
| Increaser III | *Elionurus muticus* | 0 | | 0 | 1 | 1.9 | 0.0 |
| | | **Total** | **0** | **0** | **1** | **1.9** | **0.0** |
| | | **GRAND TOTAL** | **101** | **742** | **52** | **100** | **300.0** |
| | | **SCORE** | | | | **40.4** | |

**GRAZING CAPACITY**

| | | | | |
|---|---|---|---|---|
| **Rainfall** | Mean Annual Rainfall | 750 | Effective rainfall | 600 |
| **Production** | Veld condition score | 0.404 | Production /mm rain | 2.022 |
| | Woody species impact | 1.00 | Production / ha | 1212.94 |
| | Accessibilty factor | 1.00 | | |
| **Utilization** | Utilizable production | 606.47 | Grazing period | 365 |
| **Grazing Capacity** | Domesticated livestock | 6 | Conservation | 9 |

| BIORESOURCE GROUP 12: MOIST TALL GRASSVELD | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | VELD CONDITION | | | | |
| **Smith Street** | **S28.146751** | **E30.225120** | | | | | |
| **Group** | **Species:** | **Grazing Value** | **Benchmark** | | **Site 1** | | |
| | | | **%** | **Score** | **Count** | **%** | **Score** |
| **Increaser I** | *Cymbopogon excavatus* | 1 | 1 | 1 | 17 | 33.3 | 33.3 |
| | *Hyparrhenia dregeana* | 5 | | 0 | 2 | 3.9 | 19.6 |
| | *Setaria nigrorostis* | 5 | 1 | 5 | | 0.0 | 0.0 |
| | *Tristachya leucothrix* | 9 | 17 | 153 | | 0.0 | 0.0 |
| | | **Total** | **19** | **159** | **19** | **37.3** | **52.9** |
| **Decreaser** | *Brachiaria serrata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Diheteropogon amplectens* | 8 | 1 | 8 | 4 | 7.8 | 62.7 |
| | *Melenis nerviglumis* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Themeda triandra* | 10 | 50 | 500 | 13 | 25.5 | 254.9 |
| | | **Total** | **53** | **513** | **17** | **33.3** | **317.6** |
| **Increaser IIa** | *Eragrostis capensis* | 2 | 5 | 10 | | 0.0 | 0.0 |
| | *Heteropogon contortus* | 6 | 4 | 24 | 2 | 3.9 | 23.5 |
| | | **Total** | **9** | **34** | **2** | **3.9** | **23.5** |
| **Increaser IIb** | *Eragrostis curvula* | 5 | 1 | 5 | | 0.0 | 0.0 |
| | *Eragrostis plana* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Eragrostis racemosa* | 2 | 2 | 4 | | 0.0 | 0.0 |
| | *Hyparrhenia hirta* | 6 | 2 | 12 | 6 | 11.8 | 70.6 |
| | *Sporobolus africanus* | 3 | 2 | 6 | | 0.0 | 0.0 |
| | *Setaria flabellata* | 2 | 3 | 6 | | 0.0 | 0.0 |
| | *Eragrostis chloromelas* | 0 | | | 1 | 2.0 | 0.0 |
| | | **Total** | **11** | **36** | **7** | **13.7** | **70.6** |
| **Increaser IIc** | *Aristida congesta* | 0 | 1 | 0 | 4 | 7.8 | 0.0 |
| | Forbs | 0 | 4 | 0 | | 0.0 | 0.0 |
| | Sedges | 0 | 3 | 0 | | 0.0 | 0.0 |
| | *Microloa caffra* | 0 | 1 | 0 | | 0.0 | 0.0 |
| | *Cynodon dactylon* | 3 | | 0 | | 0.0 | 0.0 |
| | *Paspalum notatum* | 3 | | 0 | | 0.0 | 0.0 |
| | | **Total** | **9** | **0** | **4** | **7.8** | **0.0** |
| **Increaser III** | *Elionurus muticus* | 0 | | 0 | 2 | 3.9 | 0.0 |
| | | **Total** | **0** | **0** | **2** | **3.9** | **0.0** |
| | | **GRAND TOTAL** | **101** | **742** | **51** | **100** | **464.7** |
| | | **SCORE** | | | | **62.6** | |

**GRAZING CAPACITY**

| | | | | |
|---|---|---|---|---|
| **Rainfall** | Mean Annual Rainfall | 750 | Effective rainfall | 600 |
| **Production** | Veld condition score | 0.626 | Production /mm rain | 3.131 |
| | Woody species impact | 1.00 | Production / ha | 1878.86 |
| | Accessibilty factor | 1.00 | | |
| **Utilization** | Utilizable production | 939.43 | Grazing period | 365 |
| **Grazing Capacity** | Domesticated livestock | 4 | Conservation | 6 |

**BIORESOURCE GROUP 12: MOIST TALL GRASSVELD**

**VELD CONDITION**

**Consol** **S28.18097** **E30.25685**

| Group | Species: | Grazing Value | Benchmark % | Benchmark Score | Site 1 Count | Site 1 % | Site 1 Score |
|---|---|---|---|---|---|---|---|
| **Increaser I** | *Cymbopogon excavatus* | 1 | 1 | 1 | 3 | 6.0 | 6.0 |
| | *Setaria nigrorostis* | 5 | 1 | 5 | | 0.0 | 0.0 |
| | *Tristachya leucothrix* | 9 | 17 | 153 | | 0.0 | 0.0 |
| | | **Total** | **19** | **159** | **3** | **6.0** | **6.0** |
| **Decreaser** | *Brachiaria serrata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Diheteropogon amplectens* | 8 | 1 | 8 | | 0.0 | 0.0 |
| | *Melenis nerviglumis* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Themeda triandra* | 10 | 50 | 500 | 7 | 14.0 | 140.0 |
| | | **Total** | **53** | **513** | **7** | **14.0** | **140.0** |
| **Increaser IIa** | *Eragrostis capensis* | 2 | 5 | 10 | | 0.0 | 0.0 |
| | *Heteropogon contortus* | 6 | 4 | 24 | 5 | 10.0 | 60.0 |
| | | **Total** | **9** | **34** | **5** | **10.0** | **60.0** |
| **Increaser IIb** | *Eragrostis curvula* | 5 | 1 | 5 | | 0.0 | 0.0 |
| | *Eragrostis plana* | 3 | 1 | 3 | 4 | 8.0 | 24.0 |
| | *Eragrostis racemosa* | 2 | 2 | 4 | | 0.0 | 0.0 |
| | *Hyparrhenia hirta* | 6 | 2 | 12 | 1 | 2.0 | 12.0 |
| | *Sporobolus africanus* | 3 | 2 | 6 | 2 | 4.0 | 12.0 |
| | *Setaria flabellata* | 2 | 3 | 6 | | 0.0 | 0.0 |
| | *Eragrostis chloromelas* | 0 | | | 6 | 12.0 | 0.0 |
| | | **Total** | **11** | **36** | **13** | **26.0** | **48.0** |
| **Increaser IIc** | *Aristida congesta* | 0 | 1 | 0 | 1 | 2.0 | 0.0 |
| | Forbs | 0 | 4 | 0 | | 0.0 | 0.0 |
| | Sedges | 0 | 3 | 0 | | 0.0 | 0.0 |
| | *Microloa caffra* | 0 | 1 | 0 | 2 | 4.0 | 0.0 |
| | *Cynodon dactylon* | 3 | | 0 | 17 | 34.0 | 102.0 |
| | *Paspalum notatum* | 3 | | 0 | | 0.0 | 0.0 |
| | | **Total** | **9** | **0** | **20** | **40.0** | **102.0** |
| **Increaser III** | *Elionurus muticus* | 0 | | 0 | 2 | 4.0 | 0.0 |
| | | **Total** | **0** | **0** | **2** | **4.0** | **0.0** |
| | | **GRAND TOTAL** | **101** | **742** | **50** | **100** | **356.0** |
| | | **SCORE** | | | | **48.0** | |

**GRAZING CAPACITY**

| | | | | |
|---|---|---|---|---|
| **Rainfall** | Mean Annual Rainfall | 750 | Effective rainfall | 600 |
| **Production** | Veld condition score | 0.480 | Production /mm rain | 2.399 |
| | Woody species impact | 1.00 | Production / ha | 1439.35 |
| | Accessibilty factor | 1.00 | | |
| **Utilization** | Utilizable production | 719.68 | Grazing period | 365 |
| **Grazing Capacity** | Domesticated livestock | 5 | Conservation | 7 |

| BIORESOURCE GROUP 14: SOUR SANDVELD | | | | | | | |
|---|---|---|---|---|---|---|---|
| VELD CONDITION | | | | | | | |
| **Lerryn Farm** | **S28.159114** | **E30.312834** | | | | | |
| **Group** | **Species:** | **Grazing Value** | **Benchmark** | | **Site 1** | | |
| | | | **%** | **Score** | **Count** | **%** | **Score** |
| **Increaser I** | *Alloteropsis semialata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Cymbopogon excavatus* | 1 | | 0 | 2 | 3.7 | 3.7 |
| | *Cymbopogon plurinoides* | 0 | | 0 | 8 | 14.8 | 0.0 |
| | *Digitaria tricholaenoides* | 6 | 12 | 72 | | 0.0 | 0.0 |
| | *Seteria nigrirostris* | 5 | 6 | 30 | 4 | 7.4 | 37.0 |
| | *Trachypogan spicatus* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Tristachya leucothrix* | 9 | 25 | 225 | | 0.0 | 0.0 |
| | | **Total** | **45** | **333** | **14** | **25.9** | **40.7** |
| **Decreaser** | *Brachiaria serrata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Dihetropogon amplectens* | 8 | 2 | 16 | | 0.0 | 0.0 |
| | *Themeda triandra* | 10 | 25 | 250 | | 0.0 | 0.0 |
| | | **Total** | **28** | **269** | **0** | **0.0** | **0.0** |
| **Increaser IIa** | *Eragrostis capensis* | 2 | 4 | 8 | 2 | 3.7 | 7.4 |
| | *Harpochloa falx* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Heteropogon contortus* | 6 | 2 | 12 | 4 | 7.4 | 44.4 |
| | | **Total** | **7** | **23** | **6** | **11.1** | **51.9** |
| **Increaser IIb** | *Eragrostis chloromelas* | 2 | 2 | 4 | | 0.0 | 0.0 |
| | *Eragrostis curvula* | 5 | 1 | 5 | 1 | 1.9 | 9.3 |
| | *Eragrostis gummiflua* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Eragrostis plana* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Eragrostis racemosa* | 2 | 4 | 8 | | 0.0 | 0.0 |
| | *Hyparrhenia hirta* | 6 | 1 | 6 | 4 | 7.4 | 44.4 |
| | *Sporobolus africanus* | 3 | 2 | 6 | | 0.0 | 0.0 |
| | | **Total** | **12** | **33** | **5** | **9.3** | **53.7** |
| **Increaser IIc** | *Aristida congesta* | 0 | 1 | 0 | | 0.0 | 0.0 |
| | Forbs | 0 | 2 | 0 | | 0.0 | 0.0 |
| | Sedges | 0 | 2 | 0 | | 0.0 | 0.0 |
| | Bareground | 0 | | 0 | | 0.0 | 0.0 |
| | *Perotis patens* | 0 | | 0 | | 0.0 | 0.0 |
| | *Cynodon dactylon* | 3 | | 0 | | 0.0 | 0.0 |
| | *Microchloa caffra* | 1 | | 0 | | 0.0 | 0.0 |
| | | **Total** | **5** | **0** | **0** | **0.0** | **0.0** |
| **Increaser III** | *Elionurus muticus* | 0 | 3 | 0 | | 0.0 | 0.0 |
| | *Aristida junciformes* | 0 | | 0 | 29 | 53.7 | 0.0 |
| | | **Total** | **3** | **0** | **29** | **53.7** | **0.0** |
| | | **GRAND TOTAL** | **100** | **658** | **54** | **100** | **146.3** |
| | | **SCORE** | | | | **22.2** | |

| GRAZING CAPACITY | | | | |
|---|---|---|---|---|
| **Rainfall** | Mean Annual Rainfall | 604 | Effective rainfall | 438.2 |
| **Production** | Veld condition score | 0.222 | Production /mm rain | 1.112 |
| | Woody species impact | 1.00 | Production / ha | 487.14 |
| | Accessibilty factor | 1.00 | | |
| **Utilization** | Utilizable production | 243.57 | Grazing period | 365 |
| **Grazing Capacity** | Domesticated livestock | 14.99 | Conservation | 21.41 |

| BIORESOURCE GROUP 14: SOUR SANDVELD | | | | | | | |
|---|---|---|---|---|---|---|---|
| VELD CONDITION | | | | | | | |
| **Ingudlane farming** | **S28.152854** | **E30.282184** | | | | | |
| **Group** | **Species:** | **Grazing Value** | **Benchmark** | | **Site 1** | | |
| | | | **%** | **Score** | **Count** | **%** | **Score** |
| **Increaser I** | *Alloteropsis semialata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Cymbopogon excavatus* | 1 | 25 | 25 | 4 | 7.4 | 7.4 |
| | *Digitaria tricholaenoides* | 6 | 12 | 72 | | 0.0 | 0.0 |
| | *Seteria nigrirostris* | 5 | 6 | 30 | 2 | 3.7 | 18.5 |
| | *Trachypogan spicatus* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Tristachya leucothrix* | 9 | 25 | 225 | | 0.0 | 0.0 |
| | | | | 0 | | 0.0 | 0.0 |
| | | **Total** | **70** | **358** | **6** | **11.1** | **25.9** |
| **Decreaser** | *Brachiaria serrata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Dihetropogon amplectens* | 8 | 2 | 16 | | 0.0 | 0.0 |
| | *Themeda triandra* | 10 | 25 | 250 | | 0.0 | 0.0 |
| | | **Total** | **28** | **269** | **0** | **0.0** | **0.0** |
| **Increaser IIa** | *Eragrostis capensis* | 2 | 4 | 8 | | 0.0 | 0.0 |
| | *Harpochloa falx* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Heteropogon contortus* | 6 | 2 | 12 | | 0.0 | 0.0 |
| | | **Total** | **7** | **23** | **0** | **0.0** | **0.0** |
| **Increaser IIb** | *Eragrostis chloromelas* | 2 | 2 | 4 | 1 | 1.9 | 3.7 |
| | *Eragrostis curvula* | 5 | 1 | 5 | 1 | 1.9 | 9.3 |
| | *Eragrostis gummiflua* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Eragrostis plana* | 2 | 1 | 2 | 14 | 25.9 | 51.9 |
| | *Eragrostis racemosa* | 2 | 4 | 8 | | 0.0 | 0.0 |
| | *Hyparrhenia hirta* | 6 | 1 | 6 | 5 | 9.3 | 55.6 |
| | *Sporobolus africanus* | 3 | 2 | 6 | 12 | 22.2 | 66.7 |
| | | **Total** | **12** | **33** | **33** | **61.1** | **187.0** |
| **Increaser IIc** | *Aristida congesta* | 0 | 1 | 0 | | 0.0 | 0.0 |
| | *Cynodon dactylon* | 3 | | 0 | 9 | 16.7 | 50.0 |
| | *Paspalum dilatatum* | 7 | | 0 | 5 | 1.1 | 8.0 |
| | Forbs | 0 | 2 | 0 | | 0.0 | 0.0 |
| | Sedges | 0 | 2 | 0 | | 0.0 | 0.0 |
| | Bareground | 0 | | 0 | | 0.0 | 0.0 |
| | *Perotis patens* | 0 | | 0 | | 0.0 | 0.0 |
| | *Microchloa caffra* | 1 | | 0 | | 0.0 | 0.0 |
| | | **Total** | **5** | **0** | **14** | **17.8** | **58.0** |
| **Increaser III** | *Elionurus muticus* | 0 | 3 | 0 | 1 | 1.9 | 0.0 |
| | | **Total** | **3** | **0** | **1** | **1.9** | **0.0** |
| | | **GRAND TOTAL** | **125** | **683** | **54** | **91.88177223** | **271.0** |
| | | **SCORE** | | | | **39.7** | |

| GRAZING CAPACITY | | | | |
|---|---|---|---|---|
| **Rainfall** | Mean Annual Rainfall | 604 | Effective rainfall | 438.2 |
| **Production** | Veld condition score | 0.397 | Production /mm rain | 1.984 |
| | Woody species impact | 1.00 | Production / ha | 869.18 |
| | Accessibilty factor | 1.00 | | |
| **Utilization** | Utilizable production | 434.59 | Grazing period | 365 |
| **Grazing Capacity** | Domesticated livestock | 8.40 | Conservation | 12.00 |

| BIORESOURCE GROUP 14: SOUR SANDVELD | | | | | | | |
|---|---|---|---|---|---|---|---|
| VELD CONDITION | | | | | | | |
| **Springfield** | **S28.146478** | **E30.280013** | | | | | |
| **Group** | **Species:** | **Grazing Value** | **Benchmark** | | **Site 1** | | |
| | | | **%** | **Score** | **Count** | **%** | **Score** |
| **Increaser I** | *Alloteropsis semialata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Cymbopogon excavatus* | 1 | 25 | 25 | 3 | 6.4 | 6.4 |
| | *Digitaria tricholaenoides* | 6 | 12 | 72 | | 0.0 | 0.0 |
| | *Seteria nigrirostris* | 5 | 6 | 30 | 4 | 8.5 | 42.6 |
| | *Trachypogan spicatus* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Tristachya leucothrix* | 9 | 25 | 225 | | 0.0 | 0.0 |
| | | | | 0 | | 0.0 | 0.0 |
| | | **Total** | **70** | **358** | **7** | **14.9** | **48.9** |
| **Decreaser** | *Brachiaria serrata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Dihetropogon amplectens* | 8 | 2 | 16 | 5 | 10.6 | 85.1 |
| | *Themeda triandra* | 10 | 25 | 250 | 9 | 19.1 | 191.5 |
| | | **Total** | **28** | **269** | **14** | **29.8** | **276.6** |
| **Increaser IIa** | *Eragrostis capensis* | 2 | 4 | 8 | 2 | 4.3 | 8.5 |
| | *Harpochloa falx* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Heteropogon contortus* | 6 | 2 | 12 | | 0.0 | 0.0 |
| | | **Total** | **7** | **23** | **2** | **4.3** | **8.5** |
| **Increaser IIb** | *Eragrostis chloromelas* | 2 | 2 | 4 | | 0.0 | 0.0 |
| | *Eragrostis curvula* | 5 | 1 | 5 | | 0.0 | 0.0 |
| | *Eragrostis gummiflua* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Eragrostis plana* | 2 | 1 | 2 | 4 | 8.5 | 17.0 |
| | *Eragrostis racemosa* | 2 | 4 | 8 | 1 | 2.1 | 4.3 |
| | *Hyparrhenia hirta* | 6 | 1 | 6 | 1 | 2.1 | 12.8 |
| | *Sporobolus africanus* | 3 | 2 | 6 | 7 | 14.9 | 44.7 |
| | | **Total** | **12** | **33** | **13** | **27.7** | **78.7** |
| **Increaser IIc** | *Aristida congesta* | 0 | 1 | 0 | 2 | 4.3 | 0.0 |
| | Forbs | 0 | 2 | 0 | | 0.0 | 0.0 |
| | Sedges | 0 | 2 | 0 | | 0.0 | 0.0 |
| | Bareground | 0 | | 0 | | 0.0 | 0.0 |
| | *Perotis patens* | 0 | | 0 | | 0.0 | 0.0 |
| | *Cynodon dactylon* | 3 | | 0 | | 0.0 | 0.0 |
| | *Microchloa caffra* | 1 | | 0 | | 0.0 | 0.0 |
| | | **Total** | **5** | **0** | **2** | **4.3** | **0.0** |
| **Increaser III** | *Elionurus muticus* | 0 | 3 | 0 | 9 | 19.1 | 0.0 |
| | | **Total** | **3** | **0** | **9** | **19.1** | **0.0** |
| | | **GRAND TOTAL** | **125** | **683** | **47** | **100** | **412.8** |
| | | **SCORE** | | | | **60.4** | |

| GRAZING CAPACITY | | | | |
|---|---|---|---|---|
| **Rainfall** | Mean Annual Rainfall | 604 | Effective rainfall | 438.2 |
| **Production** | Veld condition score | 0.604 | Production /mm rain | 3.022 |
| | Woody species impact | 1.00 | Production / ha | 1324.11 |
| | Accessibilty factor | 1.00 | | |
| **Utilization** | Utilizable production | 662.06 | Grazing period | 365 |
| **Grazing Capacity** | Domesticated livestock | 5.51 | Conservation | 7.88 |

| BIORESOURCE GROUP 12: MOIST TALL GRASSVELD | | | | | | | |
|---|---|---|---|---|---|---|---|
| VELD CONDITION | | | | | | | |
| Talana | S28.156994 | E30.248876 | | | | | |
| **Group** | **Species:** | **Grazing Value** | **Benchmark** | | **Site 1** | | |
| | | | **%** | **Score** | **Count** | **%** | **Score** |
| **Increaser I** | *Cymbopogon excavatus* | 1 | 1 | 1 | 1 | 2.0 | 2.0 |
| | *Setaria nigrorostis* | 5 | 1 | 5 | 1 | 2.0 | 10.0 |
| | *Tristachya leucothrix* | 9 | 17 | 153 | | 0.0 | 0.0 |
| | | **Total** | **19** | **159** | **2** | **4.0** | **12.0** |
| **Decreaser** | *Brachiaria serrata* | 3 | 1 | 3 | 1 | 2.0 | 6.0 |
| | *Diheteropogon amplectens* | 8 | 1 | 8 | | 0.0 | 0.0 |
| | *Melenis nerviglumis* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Themeda triandra* | 10 | 50 | 500 | 6 | 12.0 | 120.0 |
| | | | | | | 0.0 | 0.0 |
| | | **Total** | **53** | **513** | **7** | **14.0** | **126.0** |
| **Increaser IIa** | *Eragrostis capensis* | 2 | 5 | 10 | 1 | 2.0 | 4.0 |
| | *Heteropogon contortus* | 6 | 4 | 24 | 1 | 2.0 | 12.0 |
| | | | | | | 0.0 | 0.0 |
| | | **Total** | **9** | **34** | **2** | **4.0** | **16.0** |
| **Increaser IIb** | *Eragrostis curvula* | 5 | 1 | 5 | | 0.0 | 0.0 |
| | *Eragrostis plana* | 3 | 1 | 3 | 5 | 10.0 | 30.0 |
| | *Eragrostis racemosa* | 2 | 2 | 4 | | 0.0 | 0.0 |
| | *Hyparrhenia hirta* | 6 | 2 | 12 | | 0.0 | 0.0 |
| | *Sporobolus africanus* | 3 | 2 | 6 | 3 | 6.0 | 18.0 |
| | *Setaria flabellata* | 2 | 3 | 6 | | 0.0 | 0.0 |
| | *Eragrostis chloromelas* | 0 | | | 15 | 30.0 | 0.0 |
| | | **Total** | **11** | **36** | **23** | **46.0** | **48.0** |
| **Increaser IIc** | *Aristida congesta* | 0 | 1 | 0 | 7 | 14.0 | 0.0 |
| | Forbs | 0 | 4 | 0 | | 0.0 | 0.0 |
| | Sedges | 0 | 3 | 0 | | 0.0 | 0.0 |
| | *Microloa caffra* | 0 | 1 | 0 | 4 | 8.0 | 0.0 |
| | *Cynodon dactylon* | 3 | | 0 | 5 | 10.0 | 30.0 |
| | *Paspalum notatum* | 3 | | 0 | | 0.0 | 0.0 |
| | | **Total** | **9** | **0** | **16** | **32.0** | **30.0** |
| **Increaser III** | *Elionurus muticus* | 0 | | 0 | | 0.0 | 0.0 |
| | | **Total** | **0** | **0** | **0** | **0.0** | **0.0** |
| | | **GRAND TOTAL** | **101** | **742** | **50** | **100** | **232.0** |
| | | **SCORE** | | | | **31.3** | |

| GRAZING CAPACITY | | | | |
|---|---|---|---|---|
| **Rainfall** | Mean Annual Rainfall | 750 | Effective rainfall | 600 |
| **Production** | Veld condition score | 0.313 | Production /mm rain | 1.563 |
| | Woody species impact | 1.00 | Production / ha | 938.01 |
| | Accessibilty factor | 1.00 | | |
| **Utilization** | Utilizable production | 469.00 | Grazing period | 365 |
| **Grazing Capacity** | Domesticated livestock | 8 | Conservation | 11 |

| BIORESOURCE GROUP 14: SOUR SANDVELD | | | | | | | |
|---|---|---|---|---|---|---|---|
| VELD CONDITION | | | | | | | |
| **Tayside 1** | **S28.068** | **E30.3913** | | | | | |
| **Group** | **Species:** | **Grazing Value** | **Benchmark** | | **Site 1** | | |
| | | | **%** | **Score** | **Count** | **%** | **Score** |
| **Increaser I** | *Alloteropsis semialata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Cymbopogon excavatus* | 1 | 25 | 25 | 4 | 7.3 | 7.3 |
| | *Digitaria tricholaenoides* | 6 | 12 | 72 | | 0.0 | 0.0 |
| | *Hyparrhenia dregeana* | 5 | 25 | 125 | 4 | 7.3 | 36.4 |
| | *Seteria nigrirostris* | 5 | 6 | 30 | 3 | 5.5 | 27.3 |
| | *Trachypogan spicatus* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Tristachya leucothrix* | 9 | 25 | 225 | 1 | 1.8 | 16.4 |
| | | **Total** | **95** | **483** | **12** | **21.8** | **87.3** |
| **Decreaser** | *Brachiaria serrata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Dihetropogon amplectens* | 8 | 2 | 16 | | 0.0 | 0.0 |
| | *Themeda triandra* | 10 | 25 | 250 | 16 | 29.1 | 290.9 |
| | | **Total** | **28** | **269** | **16** | **29.1** | **290.9** |
| **Increaser IIa** | *Eragrostis capensis* | 2 | 4 | 8 | | 0.0 | 0.0 |
| | *Harpochloa falx* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Heteropogon contortus* | 6 | 2 | 12 | | 0.0 | 0.0 |
| | | **Total** | **7** | **23** | **0** | **0.0** | **0.0** |
| **Increaser IIb** | *Eragrostis chloromelas* | 2 | 2 | 4 | 1 | 1.8 | 3.6 |
| | *Eragrostis curvula* | 5 | 1 | 5 | | 0.0 | 0.0 |
| | *Eragrostis gummiflua* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Eragrostis plana* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Eragrostis racemosa* | 2 | 4 | 8 | | 0.0 | 0.0 |
| | *Hyparrhenia hirta* | 6 | 1 | 6 | 3 | 5.5 | 32.7 |
| | *Sporobolus africanus* | 3 | 2 | 6 | | 0.0 | 0.0 |
| | | **Total** | **12** | **33** | **4** | **7.3** | **36.4** |
| **Increaser IIc** | *Aristida congesta* | 0 | 1 | 0 | 7 | 12.7 | 0.0 |
| | Forbs | 0 | 2 | 0 | | 0.0 | 0.0 |
| | Sedges | 0 | 2 | 0 | | 0.0 | 0.0 |
| | *Bareground* | 0 | | 0 | | 0.0 | 0.0 |
| | *Perotis patens* | 0 | | 0 | | 0.0 | 0.0 |
| | *Cynodon dactylon* | 3 | | 0 | 16 | 29.1 | 87.3 |
| | *Microchloa caffra* | 1 | | 0 | | 0.0 | 0.0 |
| | | **Total** | **5** | **0** | **23** | **41.8** | **87.3** |
| **Increaser III** | *Elionurus muticus* | 0 | 3 | 0 | | 0.0 | 0.0 |
| | | **Total** | **3** | **0** | **0** | **0.0** | **0.0** |
| | | **GRAND TOTAL** | **150** | **808** | **55** | **100** | **501.8** |
| | | **SCORE** | | | | **62.1** | |

| GRAZING CAPACITY | | | | |
|---|---|---|---|---|
| **Rainfall** | Mean Annual Rainfall | 604 | Effective rainfall | 438.2 |
| **Production** | Veld condition score | 0.621 | Production /mm rain | 3.105 |
| | Woody species impact | 1.00 | Production / ha | 1360.75 |
| | Accessibilty factor | 1.00 | | |
| **Utilization** | Utilizable production | 680.37 | Grazing period | 365 |
| **Grazing Capacity** | Domesticated livestock | 5.36 | Conservation | 7.66 |

| BIORESOURCE GROUP 14: SOUR SANDVELD | | | | | | | |
|---|---|---|---|---|---|---|---|
| VELD CONDITION | | | | | | | |
| **Tayside 2** | **S28.068** | **E30.3908** | | | | | |
| **Group** | **Species:** | **Grazing Value** | **Benchmark** | | **Site 1** | | |
| | | | **%** | **Score** | **Count** | **%** | **Score** |
| **Increaser I** | *Alloteropsis semialata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Digitaria tricholaenoides* | 6 | 12 | 72 | | 0.0 | 0.0 |
| | *Seteria nigrirostris* | 5 | 6 | 30 | | 0.0 | 0.0 |
| | *Trachypogan spicatus* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Tristachya leucothrix* | 9 | 25 | 225 | | 0.0 | 0.0 |
| | | **Total** | **45** | **333** | **0** | **0.0** | **0.0** |
| **Decreaser** | *Brachiaria serrata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Dihetropogon amplectens* | 8 | 2 | 16 | | 0.0 | 0.0 |
| | *Themeda triandra* | 10 | 25 | 250 | 15 | 26.3 | 263.2 |
| | | **Total** | **28** | **269** | **15** | **26.3** | **263.2** |
| **Increaser IIa** | *Eragrostis capensis* | 2 | 4 | 8 | | 0.0 | 0.0 |
| | *Harpochloa falx* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Heteropogon contortus* | 6 | 2 | 12 | | 0.0 | 0.0 |
| | | **Total** | **7** | **23** | **0** | **0.0** | **0.0** |
| **Increaser IIb** | *Eragrostis chloromelas* | 2 | 2 | 4 | | 0.0 | 0.0 |
| | *Eragrostis curvula* | 5 | 1 | 5 | 3 | 5.3 | 26.3 |
| | *Eragrostis gummiflua* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Eragrostis plana* | 2 | 1 | 2 | 5 | 8.8 | 17.5 |
| | *Eragrostis racemosa* | 2 | 4 | 8 | | 0.0 | 0.0 |
| | *Hyparrhenia hirta* | 6 | 1 | 6 | 3 | 5.3 | 31.6 |
| | *Sporobolus africanus* | 3 | 2 | 6 | 2 | 3.5 | 10.5 |
| | | **Total** | **12** | **33** | **13** | **22.8** | **86.0** |
| **Increaser IIc** | *Aristida congesta* | 0 | 1 | 0 | 25 | 43.9 | 0.0 |
| | *Forbs* | 0 | 2 | 0 | | 0.0 | 0.0 |
| | *Sedges* | 0 | 2 | 0 | | 0.0 | 0.0 |
| | *Bareground* | 0 | | 0 | | 0.0 | 0.0 |
| | *Perotis patens* | 0 | | 0 | | 0.0 | 0.0 |
| | *Cynodon dactylon* | 3 | | 0 | 2 | 3.5 | 10.5 |
| | *Urochloa panicoides* | 2 | | 0 | 1 | 1.8 | 3.5 |
| | *Tragus berteronianus* | 1 | | 0 | 1 | 1.8 | 1.8 |
| | *Microchloa caffra* | 1 | | 0 | | 0.0 | 0.0 |
| | | **Total** | **5** | **0** | **29** | **50.9** | **15.8** |
| **Increaser III** | *Elionurus muticus* | 0 | 3 | 0 | | 0.0 | 0.0 |
| | | **Total** | **3** | **0** | **0** | **0.0** | **0.0** |
| | | **GRAND TOTAL** | **100** | **658** | **57** | **100** | **364.9** |
| | | **SCORE** | | | | **55.5** | |

| GRAZING CAPACITY | | | | |
|---|---|---|---|---|
| **Rainfall** | Mean Annual Rainfall | 604 | Effective rainfall | 438.2 |
| **Production** | Veld condition score | 0.555 | Production /mm rain | 2.773 |
| | Woody species impact | 1.00 | Production / ha | 1215.08 |
| | Accessibilty factor | 1.00 | | |
| **Utilization** | Utilizable production | 607.54 | Grazing period | 365 |
| **Grazing Capacity** | Domesticated livestock | 6.01 | Conservation | 8.58 |

| BIORESOURCE GROUP 14: SOUR SANDVELD | | | | | | | |
|---|---|---|---|---|---|---|---|
| VELD CONDITION | | | | | | | |
| Malonjeni 1 | S28.1136 | E30.3586 | | | | | |
| Group | Species: | Grazing Value | Benchmark | | Site 1 | | |
| | | | % | Score | Count | % | Score |
| Increaser I | *Alloteropsis semialata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Digitaria tricholaenoides* | 6 | 12 | 72 | | 0.0 | 0.0 |
| | *Seteria nigrirostris* | 5 | 6 | 30 | | 0.0 | 0.0 |
| | *Trachypogan spicatus* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Tristachya leucothrix* | 9 | 25 | 225 | | 0.0 | 0.0 |
| | | Total | 45 | 333 | 0 | 0.0 | 0.0 |
| Decreaser | *Brachiaria serrata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Dihetropogon amplectens* | 8 | 2 | 16 | | 0.0 | 0.0 |
| | *Themeda triandra* | 10 | 25 | 250 | 3 | 5.9 | 58.8 |
| | | Total | 28 | 269 | 3 | 5.9 | 58.8 |
| Increaser IIa | *Eragrostis capensis* | 2 | 4 | 8 | | 0.0 | 0.0 |
| | *Harpochloa falx* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Heteropogon contortus* | 6 | 2 | 12 | 12 | 23.5 | 141.2 |
| | | Total | 7 | 23 | 12 | 23.5 | 141.2 |
| Increaser IIb | *Eragrostis chloromelas* | 2 | 2 | 4 | 8 | 15.7 | 31.4 |
| | *Eragrostis curvula* | 5 | 1 | 5 | | 0.0 | 0.0 |
| | *Eragrostis gummiflua* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Eragrostis plana* | 2 | 1 | 2 | 2 | 3.9 | 7.8 |
| | *Eragrostis racemosa* | 2 | 4 | 8 | | 0.0 | 0.0 |
| | *Hyparrhenia hirta* | 6 | 1 | 6 | 3 | 5.9 | 35.3 |
| | *Sporobolus africanus* | 3 | 2 | 6 | 3 | 5.9 | 17.6 |
| | | Total | 12 | 33 | 16 | 31.4 | 92.2 |
| Increaser IIc | *Aristida congesta* | 0 | 1 | 0 | | 0.0 | 0.0 |
| | Forbs | 0 | 2 | 0 | | 0.0 | 0.0 |
| | Sedges | 0 | 2 | 0 | | 0.0 | 0.0 |
| | *Bareground* | 0 | | 0 | | 0.0 | 0.0 |
| | *Perotis patens* | 0 | | 0 | | 0.0 | 0.0 |
| | *Cynodon dactylon* | 3 | | 0 | 5 | 9.8 | 29.4 |
| | *Microchloa caffra* | 1 | | 0 | | 0.0 | 0.0 |
| | | Total | 5 | 0 | 5 | 9.8 | 29.4 |
| Increaser III | *Elionurus muticus* | 0 | 3 | 0 | | 0.0 | 0.0 |
| | *Aristida junciformes* | 0 | | 0 | 15 | 29.4 | 0.0 |
| | | Total | 3 | 0 | 15 | 29.4 | 0.0 |
| | | GRAND TOTAL | 100 | 658 | 51 | 100 | 321.6 |
| | | SCORE | | | | 48.9 | |

| GRAZING CAPACITY | | | | |
|---|---|---|---|---|
| Rainfall | Mean Annual Rainfall | 604 | Effective rainfall | 438.2 |
| Production | Veld condition score | 0.489 | Production /mm rain | 2.444 |
| | Woody species impact | 1.00 | Production / ha | 1070.76 |
| | Accessibilty factor | 1.00 | | |
| Utilization | Utilizable production | 535.38 | Grazing period | 365 |
| Grazing Capacity | Domesticated livestock | 6.82 | Conservation | 9.74 |

| BIORESOURCE GROUP 14: SOUR SANDVELD | | | | | | | |
|---|---|---|---|---|---|---|---|
| VELD CONDITION | | | | | | | |
| **Malonjeni 2** | **S28.1139** | **E30.3586** | | | | | |
| **Group** | **Species:** | **Grazing Value** | **Benchmark** | | **Site 1** | | |
| | | | **%** | **Score** | **Count** | **%** | **Score** |
| **Increaser I** | *Alloteropsis semialata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Digitaria tricholaenoides* | 6 | 12 | 72 | | 0.0 | 0.0 |
| | *Seteria nigrirostris* | 5 | 6 | 30 | | 0.0 | 0.0 |
| | *Trachypogan spicatus* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Tristachya leucothrix* | 9 | 25 | 225 | | 0.0 | 0.0 |
| | | **Total** | **45** | **333** | **0** | **0.0** | **0.0** |
| **Decreaser** | *Brachiaria serrata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Dihetropogon amplectens* | 8 | 2 | 16 | | 0.0 | 0.0 |
| | *Themeda triandra* | 10 | 25 | 250 | | 0.0 | 0.0 |
| | | **Total** | **28** | **269** | **0** | **0.0** | **0.0** |
| **Increaser IIa** | *Eragrostis capensis* | 2 | 4 | 8 | | 0.0 | 0.0 |
| | *Harpochloa falx* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Heteropogon contortus* | 6 | 2 | 12 | | 0.0 | 0.0 |
| | | **Total** | **7** | **23** | **0** | **0.0** | **0.0** |
| **Increaser IIb** | *Eragrostis chloromelas* | 2 | 2 | 4 | 2 | 4.1 | 8.2 |
| | *Eragrostis curvula* | 5 | 1 | 5 | 4 | 8.2 | 40.8 |
| | *Eragrostis gummiflua* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Eragrostis plana* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Eragrostis racemosa* | 2 | 4 | 8 | | 0.0 | 0.0 |
| | *Hyparrhenia hirta* | 6 | 1 | 6 | 1 | 2.0 | 12.2 |
| | *Sporobolus africanus* | 3 | 2 | 6 | | 0.0 | 0.0 |
| | | **Total** | **12** | **33** | **7** | **14.3** | **61.2** |
| **Increaser IIc** | *Aristida congesta* | 0 | 1 | 0 | | 0.0 | 0.0 |
| | Forbs | 0 | 2 | 0 | | 0.0 | 0.0 |
| | Sedges | 0 | 2 | 0 | | 0.0 | 0.0 |
| | Bareground | 0 | | 0 | | 0.0 | 0.0 |
| | *Perotis patens* | 0 | | 0 | | 0.0 | 0.0 |
| | *Cynodon dactylon* | 3 | | 0 | 39 | 79.6 | 238.8 |
| | *Microchloa caffra* | 1 | | 0 | | 0.0 | 0.0 |
| | | **Total** | **5** | **0** | **39** | **79.6** | **238.8** |
| **Increaser III** | *Elionurus muticus* | 0 | 3 | 0 | | 0.0 | 0.0 |
| | *Aristida junciformes* | 0 | | 0 | 3 | 6.1 | 0.0 |
| | | **Total** | **3** | **0** | **3** | **6.1** | **0.0** |
| | | **GRAND TOTAL** | **100** | **658** | **49** | **100** | **300.0** |
| | | **SCORE** | | | | **45.6** | |

**GRAZING CAPACITY**

| | | | | |
|---|---|---|---|---|
| **Rainfall** | Mean Annual Rainfall | 604 | Effective rainfall | 438.2 |
| **Production** | Veld condition score | 0.456 | Production /mm rain | 2.280 |
| | Woody species impact | 1.00 | Production / ha | 998.94 |
| | Accessibilty factor | 1.00 | | |
| **Utilization** | Utilizable production | 499.47 | Grazing period | 365 |
| **Grazing Capacity** | Domesticated livestock | 7.31 | Conservation | 10.44 |

| BIORESOURCE GROUP 14: SOUR SANDVELD | | | | | | | |
|---|---|---|---|---|---|---|---|
| VELD CONDITION | | | | | | | |
| **Triple C** | **S28.132822** | **E30.358751** | | | | | |
| **Group** | **Species:** | **Grazing Value** | **Benchmark** | | **Site 1** | | |
| | | | **%** | **Score** | **Count** | **%** | **Score** |
| **Increaser I** | *Alloteropsis semialata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Digitaria tricholaenoides* | 6 | 12 | 72 | | 0.0 | 0.0 |
| | *Seteria nigrirostris* | 5 | 6 | 30 | | 0.0 | 0.0 |
| | *Trachypogan spicatus* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Tristachya leucothrix* | 9 | 25 | 225 | | 0.0 | 0.0 |
| | | **Total** | **45** | **333** | **0** | **0.0** | **0.0** |
| **Decreaser** | *Brachiaria serrata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Dihetropogon amplectens* | 8 | 2 | 16 | | 0.0 | 0.0 |
| | *Themeda triandra* | 10 | 25 | 250 | | 0.0 | 0.0 |
| | | **Total** | **28** | **269** | **0** | **0.0** | **0.0** |
| **Increaser IIa** | *Eragrostis capensis* | 2 | 4 | 8 | | 0.0 | 0.0 |
| | *Harpochloa falx* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Heteropogon contortus* | 6 | 2 | 12 | | 0.0 | 0.0 |
| | | **Total** | **7** | **23** | **0** | **0.0** | **0.0** |
| **Increaser IIb** | *Eragrostis chloromelas* | 2 | 2 | 4 | 2 | 4.0 | 8.0 |
| | *Eragrostis curvula* | 5 | 1 | 5 | 1 | 2.0 | 10.0 |
| | *Eragrostis gummiflua* | 2 | 1 | 2 | 2 | 4.0 | 8.0 |
| | *Eragrostis plana* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Eragrostis racemosa* | 2 | 4 | 8 | | 0.0 | 0.0 |
| | *Hyparrhenia hirta* | 6 | 1 | 6 | | 0.0 | 0.0 |
| | *Sporobolus africanus* | 3 | 2 | 6 | 3 | 6.0 | 18.0 |
| | | **Total** | **12** | **33** | **8** | **16.0** | **44.0** |
| **Increaser IIc** | *Aristida congesta* | 0 | 1 | 0 | 4 | 8.0 | 0.0 |
| | Forbs | 0 | 2 | 0 | | 0.0 | 0.0 |
| | Sedges | 0 | 2 | 0 | | 0.0 | 0.0 |
| | Bareground | 0 | | 0 | | 0.0 | 0.0 |
| | *Perotis patens* | 0 | | 0 | | 0.0 | 0.0 |
| | *Cynodon dactylon* | 3 | | 0 | 36 | 72.0 | 216.0 |
| | *Microchloa caffra* | 1 | | 0 | | 0.0 | 0.0 |
| | | **Total** | **5** | **0** | **40** | **80.0** | **216.0** |
| **Increaser III** | *Elionurus muticus* | 0 | 3 | 0 | | 0.0 | 0.0 |
| | *Aristida junciformes* | 0 | | 0 | 2 | 4.0 | 0.0 |
| | | **Total** | **3** | **0** | **2** | **4.0** | **0.0** |
| | | **GRAND TOTAL** | **100** | **658** | **50** | **100** | **260.0** |
| | | **SCORE** | | | | **39.5** | |

| GRAZING CAPACITY | | | | |
|---|---|---|---|---|
| **Rainfall** | Mean Annual Rainfall | 604 | Effective rainfall | 438.2 |
| **Production** | Veld condition score | 0.395 | Production /mm rain | 1.976 |
| | Woody species impact | 1.00 | Production / ha | 865.74 |
| | Accessibilty factor | 1.00 | | |
| **Utilization** | Utilizable production | 432.87 | Grazing period | 365 |
| **Grazing Capacity** | Domesticated livestock | 8.43 | Conservation | 12.05 |

| BIORESOURCE GROUP 14: SOUR SANDVELD | | | | | | | |
|---|---|---|---|---|---|---|---|
| VELD CONDITION | | | | | | | |
| **Nquthu Road 1** | **S28.173931** | **E30.445147** | | | | | |
| **Group** | **Species:** | **Grazing Value** | **Benchmark** | | **Site 1** | | |
| | | | **%** | **Score** | **Count** | **%** | **Score** |
| **Increaser I** | *Alloteropsis semialata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Cymbopogon excavatus* | 1 | 25 | 25 | 1 | 2.0 | 2.0 |
| | *Digitaria tricholaenoides* | 6 | 12 | 72 | | 0.0 | 0.0 |
| | *Seteria nigrirostris* | 5 | 6 | 30 | | 0.0 | 0.0 |
| | *Trachypogan spicatus* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Tristachya leucothrix* | 9 | 25 | 225 | | 0.0 | 0.0 |
| | | **Total** | **70** | **358** | **1** | **2.0** | **2.0** |
| **Decreaser** | *Brachiaria serrata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Dihetropogon amplectens* | 8 | 2 | 16 | 2 | 4.0 | 32.0 |
| | *Themeda triandra* | 10 | 25 | 250 | 8 | 16.0 | 160.0 |
| | | **Total** | **28** | **269** | **10** | **20.0** | **192.0** |
| **Increaser IIa** | *Eragrostis capensis* | 2 | 4 | 8 | | 0.0 | 0.0 |
| | *Harpochloa falx* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Heteropogon contortus* | 6 | 2 | 12 | | 0.0 | 0.0 |
| | | **Total** | **7** | **23** | **0** | **0.0** | **0.0** |
| **Increaser IIb** | *Eragrostis chloromelas* | 2 | 2 | 4 | 1 | 2.0 | 4.0 |
| | *Eragrostis curvula* | 5 | 1 | 5 | | 0.0 | 0.0 |
| | *Eragrostis gummiflua* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Eragrostis plana* | 2 | 1 | 2 | 8 | 16.0 | 32.0 |
| | *Eragrostis racemosa* | 2 | 4 | 8 | 1 | 2.0 | 4.0 |
| | *Hyparrhenia hirta* | 6 | 1 | 6 | 7 | 14.0 | 84.0 |
| | *Sporobolus africanus* | 3 | 2 | 6 | 4 | 8.0 | 24.0 |
| | | **Total** | **12** | **33** | **21** | **42.0** | **148.0** |
| **Increaser IIc** | *Aristida congesta* | 0 | 1 | 0 | 9 | 18.0 | 0.0 |
| | Forbs | 0 | 2 | 0 | | 0.0 | 0.0 |
| | Sedges | 0 | 2 | 0 | | 0.0 | 0.0 |
| | Bareground | 0 | | 0 | | 0.0 | 0.0 |
| | *Perotis patens* | 0 | | 0 | | 0.0 | 0.0 |
| | *Cynodon dactylon* | 3 | | 0 | 4 | 8.0 | 24.0 |
| | *Microchloa caffra* | 1 | | 0 | | 0.0 | 0.0 |
| | | **Total** | **5** | **0** | **13** | **26.0** | **24.0** |
| **Increaser III** | *Elionurus muticus* | 0 | 3 | 0 | 5 | 10.0 | 0.0 |
| | | **Total** | **3** | **0** | **5** | **10.0** | **0.0** |
| | | **GRAND TOTAL** | **125** | **683** | **50** | **100** | **366.0** |
| | | **SCORE** | | | | **53.6** | |

| GRAZING CAPACITY | | | | |
|---|---|---|---|---|
| **Rainfall** | Mean Annual Rainfall | 604 | Effective rainfall | 438.2 |
| **Production** | Veld condition score | 0.536 | Production /mm rain | 2.679 |
| | Woody species impact | 1.00 | Production / ha | 1174.09 |
| | Accessibilty factor | 1.00 | | |
| **Utilization** | Utilizable production | 587.05 | Grazing period | 365 |
| **Grazing Capacity** | Domesticated livestock | 6.22 | Conservation | 8.88 |

| BIORESOURCE GROUP 14: SOUR SANDVELD | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | VELD CONDITION | | | | |
| **Nquthu Road 2** | **S28.2383** | **E30.4883** | | | | | |
| **Group** | **Species:** | **Grazing Value** | **Benchmark** | | **Site 1** | | |
| | | | **%** | **Score** | **Count** | **%** | **Score** |
| **Increaser I** | *Alloteropsis semialata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Digitaria tricholaenoides* | 6 | 12 | 72 | 3 | 5.8 | 34.6 |
| | *Seteria nigrirostris* | 5 | 6 | 30 | | 0.0 | 0.0 |
| | *Trachypogan spicatus* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Tristachya leucothrix* | 9 | 25 | 225 | | 0.0 | 0.0 |
| | | **Total** | **45** | **333** | **3** | **5.8** | **34.6** |
| **Decreaser** | *Brachiaria serrata* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Dihetropogon amplectens* | 8 | 2 | 16 | | 0.0 | 0.0 |
| | *Themeda triandra* | 10 | 25 | 250 | | 0.0 | 0.0 |
| | | **Total** | **28** | **269** | **0** | **0.0** | **0.0** |
| **Increaser IIa** | *Eragrostis capensis* | 2 | 4 | 8 | | 0.0 | 0.0 |
| | *Harpochloa falx* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Heteropogon contortus* | 6 | 2 | 12 | 2 | 3.8 | 23.1 |
| | | **Total** | **7** | **23** | **2** | **3.8** | **23.1** |
| **Increaser IIb** | *Eragrostis chloromelas* | 2 | 2 | 4 | | 0.0 | 0.0 |
| | *Eragrostis curvula* | 5 | 1 | 5 | | 0.0 | 0.0 |
| | *Eragrostis gummiflua* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Eragrostis plana* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Eragrostis racemosa* | 2 | 4 | 8 | | 0.0 | 0.0 |
| | *Hyparrhenia hirta* | 6 | 1 | 6 | 16 | 30.8 | 184.6 |
| | *Sporobolus africanus* | 3 | 2 | 6 | 2 | 3.8 | 11.5 |
| | | **Total** | **12** | **33** | **18** | **34.6** | **196.2** |
| **Increaser IIc** | *Aristida congesta* | 0 | 1 | 0 | 2 | 3.8 | 0.0 |
| | *Aristida bipartita* | 0 | | 0 | 5 | 9.6 | 0.0 |
| | Forbs | 0 | 2 | 0 | | 0.0 | 0.0 |
| | Sedges | 0 | 2 | 0 | | 0.0 | 0.0 |
| | Bareground | 0 | | 0 | | 0.0 | 0.0 |
| | *Pogonarthria squarrosa* | 0 | | 0 | 6 | 11.5 | 0.0 |
| | *Trichoneura grandiglumis* | 0 | | 0 | 1 | 0.2 | 0.0 |
| | *Perotis patens* | 0 | | 0 | 9 | 2.1 | 0.0 |
| | *Cynodon dactylon* | 3 | | 0 | 6 | 11.5 | 34.6 |
| | *Microchloa caffra* | 1 | | 0 | | 0.0 | 0.0 |
| | | **Total** | **5** | **0** | **29** | **38.8** | **34.6** |
| **Increaser III** | *Elionurus muticus* | 0 | 3 | 0 | | 0.0 | 0.0 |
| | | | | 0 | | | |
| | | **Total** | **3** | **0** | **0** | **0.0** | **0.0** |
| | | **GRAND TOTAL** | **100** | **658** | **52** | **83.05129375** | **288.5** |
| | | **SCORE** | | | | **43.8** | |

| GRAZING CAPACITY | | | | |
|---|---|---|---|---|
| **Rainfall** | Mean Annual Rainfall | 604 | Effective rainfall | 438.2 |
| **Production** | Veld condition score | 0.438 | Production /mm rain | 2.192 |
| | Woody species impact | 1.00 | Production / ha | 960.52 |
| | Accessibilty factor | 1.00 | | |
| **Utilization** | Utilizable production | 480.26 | Grazing period | 365 |
| **Grazing Capacity** | Domesticated livestock | 7.60 | Conservation | 10.86 |

| BIORESOURCE GROUP 12: MOIST TALL GRASSVELD | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | VELD CONDITION | | | | |
| Muller | S28.392 | E30.3616 | | | | | |
| Group | Species: | Grazing Value | Benchmark | | Site 1 | | |
| | | | % | Score | Count | % | Score |
| Increaser I | *Cymbopogon excavatus* | 1 | 1 | 1 | | 0.0 | 0.0 |
| | *Setaria nigrorostis* | 5 | 1 | 5 | | 0.0 | 0.0 |
| | *Tristachya leucothrix* | 9 | 17 | 153 | 4 | 8.0 | 72.0 |
| | | **Total** | **19** | **159** | **4** | **8.0** | **72.0** |
| Decreaser | *Brachiaria serrata* | 3 | 1 | 3 | 2 | 4.0 | 12.0 |
| | *Diheteropogon amplectens* | 8 | 1 | 8 | 8 | 16.0 | 128.0 |
| | *Melenis nerviglumis* | 2 | 1 | 2 | | 0.0 | 0.0 |
| | *Themeda triandra* | 10 | 50 | 500 | 2 | 4.0 | 40.0 |
| | | **Total** | **53** | **513** | **12** | **24.0** | **180.0** |
| Increaser IIa | *Eragrostis capensis* | 2 | 5 | 10 | 4 | 8.0 | 16.0 |
| | *Heteropogon contortus* | 6 | 4 | 24 | 6 | 12.0 | 72.0 |
| | | **Total** | **9** | **34** | **10** | **20.0** | **88.0** |
| Increaser IIb | *Eragrostis curvula* | 5 | 1 | 5 | 9 | 18.0 | 90.0 |
| | *Eragrostis plana* | 3 | 1 | 3 | | 0.0 | 0.0 |
| | *Eragrostis racemosa* | 2 | 2 | 4 | | 0.0 | 0.0 |
| | *Hyparrhenia hirta* | 6 | 2 | 12 | | 0.0 | 0.0 |
| | *Sporobolus africanus* | 3 | 2 | 6 | 7 | 14.0 | 42.0 |
| | *Setaria flabellata* | 2 | 3 | 6 | | 0.0 | 0.0 |
| | *Eragrostis chloromelas* | 0 | | | 5 | 10.0 | 0.0 |
| | | **Total** | **11** | **36** | **21** | **42.0** | **132.0** |
| Increaser IIc | *Aristida congesta* | 0 | 1 | 0 | 3 | 6.0 | 0.0 |
| | *Forbs* | 0 | 4 | 0 | | 0.0 | 0.0 |
| | *Sedges* | 0 | 3 | 0 | | 0.0 | 0.0 |
| | *Microloa caffra* | 0 | 1 | 0 | | 0.0 | 0.0 |
| | *Cynodon dactylon* | 3 | | 0 | | 0.0 | 0.0 |
| | *Paspalum notatum* | 3 | | 0 | | 0.0 | 0.0 |
| | | **Total** | **9** | **0** | **3** | **6.0** | **0.0** |
| Increaser III | *Elionurus muticus* | 0 | | 0 | | 0.0 | 0.0 |
| | | **Total** | **0** | **0** | **0** | **0.0** | **0.0** |
| | | **GRAND TOTAL** | **101** | **742** | **50** | **100** | **472.0** |
| | | **SCORE** | | | | **63.6** | |

**GRAZING CAPACITY**

| | | | | |
|---|---|---|---|---|
| **Rainfall** | Mean Annual Rainfall | 750 | Effective rainfall | 600 |
| **Production** | Veld condition score | 0.636 | Production /mm rain | 3.181 |
| | Woody species impact | 1.00 | Production / ha | 1908.36 |
| | Accessibilty factor | 1.00 | | |
| **Utilization** | Utilizable production | 954.18 | Grazing period | 365 |
| **Grazing Capaci** | Domesticated livestock | 4 | Conservation | 5 |

Fire lily plant emergence rain 2 weeks before 2015.rtf

## Fire lily distribution in KZN: emergence of plants during 2015 - rainfall from 2 weeks before recording

| Identifier | Minimum | Mean | Maximum | Values | Missing | |
|---|---|---|---|---|---|---|
| Nplants | 1.000 | 3.037 | 18.00 | 54 | 0 | Skew |
| AveRain | 0.0000 | 0.7035 | 3.990 | 54 | 0 | Skew |
| AveMinT | 9.370 | 10.84 | 13.09 | 54 | 0 | |
| AveMaxT | 22.37 | 26.34 | 33.30 | 54 | 0 | |
| AveMinRH | 14.75 | 29.23 | 40.51 | 54 | 0 | |
| AveMaxRH | 84.25 | 88.36 | 92.13 | 54 | 0 | |
| AveRainBefore2 | 0.0000 | 0.4685 | 9.110 | 54 | 0 | Skew |
| AveMinTbefore2 | 1.430 | 10.04 | 12.84 | 54 | 0 | Skew |
| AveMaxTbefore2 | 16.90 | 25.96 | 33.30 | 54 | 0 | |
| AveMinRHbefore2 | 11.08 | 28.51 | 44.27 | 54 | 0 | |
| AveMaxRHbefore2 | 80.49 | 88.30 | 93.23 | 54 | 0 | |

===== Stepwise regression analysis on number of plants emerged and climate variables =====

## Regression analysis

Response variate: Nplants
Distribution: Poisson
Link function: Log
Fitted terms: Constant + AveMinRH + AveMinRH.Treatment + AveMinTbefore2 + AveMinT + AveRainBefore2 + AveMinT.Treatment + AveMinTbefore2.Treatment

## Accumulated analysis of deviance

| Change | d.f. | deviance | mean deviance | deviance ratio | approx chi pr |
|---|---|---|---|---|---|
| + AveMinRH | 1 | 39.097 | 39.097 | 39.10 | <.001 |
| + AveMinRH.Treatment | 6 | 41.022 | 6.837 | 6.84 | <.001 |
| + AveMinRHbefore2 | 1 | 5.915 | 5.915 | 5.92 | 0.015 |
| + AveMinTbefore2 | 1 | 2.534 | 2.534 | 2.53 | 0.111 |
| + AveMinT | 1 | 6.834 | 6.834 | 6.83 | 0.009 |
| + AveRainBefore2 | 1 | 4.497 | 4.497 | 4.50 | 0.034 |
| + AveMinT.Treatment | 6 | 7.904 | 1.317 | 1.32 | 0.245 |
| + AveMinTbefore2.Treatment | 6 | 18.177 | 3.029 | 3.03 | 0.006 |
| Residual | 31 | 32.117 | 1.036 | | |
| Total | 53 | 157.271 | 2.967 | | |

*Message: ratios are based on dispersion parameter with value 1.*

Fire lily plant emergence rain 2 weeks before 2016.rtf

## Fire lily distribution in KZN: emergence of plants during 2016 - rainfall from 2 weeks before recording

| Identifier | Minimum | Mean | Maximum | Values | Missing | |
|---|---|---|---|---|---|---|
| Nplants | 1.000 | 2.709 | 19.00 | 55 | 0 | Skew |
| AveRain | 0.0000 | 1.822 | 6.310 | 55 | 0 | |
| AveMinT | 5.500 | 9.433 | 14.80 | 55 | 0 | |
| AveMaxT | 20.31 | 24.13 | 29.68 | 55 | 0 | |
| AveMinRH | 13.44 | 31.60 | 35.60 | 55 | 0 | Skew |
| AveMaxRH | 84.88 | 89.43 | 93.66 | 55 | 0 | |
| AveRainBefore2 | 0.0000 | 1.869 | 6.310 | 55 | 0 | |
| AveMinTbefore2 | 5.480 | 9.197 | 12.10 | 55 | 0 | |
| AveMaxTbefore2 | 20.31 | 24.08 | 29.51 | 55 | 0 | |
| AveMinRHbefore2 | 10.05 | 31.15 | 35.60 | 55 | 0 | Skew |
| AveMaxRHbefore2 | 76.49 | 89.08 | 93.66 | 55 | 0 | |

===== Stepwise regression analysis on number of plants emerged and climate variables =====

## Regression analysis

Response variate: Nplants
Distribution: Poisson
Link function: Log
Fitted terms: Constant + AveRainBefore2 + AveRainBefore2.Treatment + AveRain

## Accumulated analysis of deviance

| Change | d.f. | deviance | mean deviance | deviance ratio | approx chi pr |
|---|---|---|---|---|---|
| + AveRainBefore2 | 1 | 34.880 | 34.880 | 34.88 | <.001 |
| + AveRainBefore2.Treatment | 6 | 29.562 | 4.927 | 4.93 | <.001 |
| + AveRain | 1 | 2.262 | 2.262 | 2.26 | 0.133 |
| Residual | 46 | 51.802 | 1.126 | | |
| Total | 54 | 118.506 | 2.195 | | |

*Message: ratios are based on dispersion parameter with value 1.*

Fire lily plant emergence rain 2 weeks before 2015_2016.rtf

## Fire lily distribution in KZN: emergence of plants during 2015-2016: rainfall from 2 weeks before recording

| Identifier | Minimum | Mean | Maximum | Values | Missing | |
|---|---|---|---|---|---|---|
| Nplants | 1.000 | 2.872 | 19.00 | 109 | 0 | Skew |
| AveRain | 0.0000 | 1.268 | 6.310 | 109 | 0 | Skew |
| AveMinT | 5.500 | 10.13 | 14.80 | 109 | 0 | |
| AveMaxT | 20.31 | 25.24 | 33.30 | 109 | 0 | |
| AveMinRH | 13.44 | 30.42 | 40.51 | 109 | 0 | |
| AveMaxRH | 84.25 | 88.90 | 93.66 | 109 | 0 | |
| AveRainBefore2 | 0.0000 | 1.274 | 6.310 | 109 | 0 | Skew |
| AveMinTbefore2 | 5.480 | 9.932 | 12.84 | 109 | 0 | |
| AveMaxTbefore2 | 18.28 | 25.15 | 33.30 | 109 | 0 | |
| AveMinRHbefore2 | 10.05 | 30.15 | 43.81 | 109 | 0 | |
| AveMaxRHbefore2 | 76.49 | 88.83 | 93.66 | 109 | 0 | |

=== Combined stepwise regression analysis on number of plants emerged and climate variables ===

## Regression analysis

Response variate: Nplants
Distribution: Poisson
Link function: Log
Fitted terms: Constant + Treatment + AveMinRH + AveRainBefore2 + AveMaxRH + AveMinRH.Treatment + AveMinT

## Accumulated analysis of deviance

| Change | d.f. | deviance | mean deviance | deviance ratio | approx chi pr |
|---|---|---|---|---|---|
| + Treatment | 6 | 59.145 | 9.858 | 9.86 | <.001 |
| + AveMinRH | 1 | 37.095 | 37.095 | 37.10 | <.001 |
| + AveRainBefore2 | 1 | 11.952 | 11.952 | 11.95 | <.001 |
| + AveMaxRH | 1 | 7.275 | 7.275 | 7.28 | 0.007 |
| + AveMinRH.Treatment | 6 | 14.848 | 2.475 | 2.47 | 0.021 |
| + AveMinT | 1 | 3.577 | 3.577 | 3.58 | 0.059 |
| Residual | 92 | 142.905 | 1.553 | | |
| Total | 108 | 276.798 | 2.563 | | |

*Message: ratios are based on dispersion parameter with value 1.*

Fire lily plant emergence 2015_2016.rtf

## Fire lily distribution in KZN: number of plants emerged during 2015 & 2016

| Identifier | Minimum | Mean | Maximum | Values | Missing | |
|---|---|---|---|---|---|---|
| plants | 1.000 | 7.452 | 31.00 | 42 | 0 | Skew |

**Statistical Analysis**

Counts are skew distributed and therefore generalized linear mixed model (GLMM) analysis was applied to the plant emergence data with the Poisson distribution and logarithm link function (Dobson, 1983) to test for differences between the seven treatments effects per season. Thereafter, a combined analysis was done to test for differences between seasons, treatments and the season by treatment interaction effects. Treatment means were compared with Fisher's protected least significant test at the 5% level (Snedecor & Cochran, 1980). Data were analysed using the statistical program GenStat® (2015).

References

Dobson, A.J. 1983. An Introduction to Statistical Modelling. Chapman & Hall, London.

GenStat® for Windows™ (18th Edition) – Introduction (Editor R.W. Payne), © 2015, VSN International, ISBN 1-904375-08-1. Website: http://www.genstat.co.uk/

SNEDECOR, GW & COCHRAN, WG. 1980. Statistical methods (7th Ed.). Iowa State University Press, pp 507.

===== GLMM analysis on number of plants emerged in season 2015 =====

## Generalized linear mixed model analysis

| | |
|---|---|
| Method: | c.f. Schall (1991) Biometrika |
| Response variate: | plants |
| Distribution: | poisson |
| Link function: | logarithm |
| Random model: | Rep |
| Fixed model: | Constant + Treatment |

Dispersion parameter fixed at value 1.000

### Estimated variance components

| Random term | component | s.e. |
|---|---|---|
| Rep | 0.357 | 0.377 |

### Residual variance model

| Term | Model(order) | Parameter | Estimate | s.e. |
|---|---|---|---|---|
| Dispersn | Identity | Sigma2 | 1.000 | fixed |

### Tests for fixed effects

Sequentially adding terms to fixed model

| Fixed term | Wald statistic | n.d.f. | F statistic | d.d.f. | F pr |
|---|---|---|---|---|---|
| Treatment | 50.00 | 6 | 8.33 | 12.0 | 0.001 |

## Back-transformed Means (on the original scale)

| Treatment | |
|---|---|
| B | 11.239 a |
| BC | 14.788 a |
| BP | 4.437 b |
| BPC | 4.732 b |
| C | 2.662 b |
| CC | 5.915 b |
| Control | 4.732 b |

========== Summary of mean counts and SDs ==========

| | Nobservd | Mean | s.d. |
|---|---|---|---|
| Treatment | | | |
| B | 3 | 12.667 | 11.590 |
| BC | 3 | 16.667 | 12.423 |
| BP | 3 | 5.000 | 4.359 |
| BPC | 3 | 5.333 | 3.055 |
| C | 3 | 3.000 | 1.732 |
| CC | 3 | 6.667 | 4.509 |
| Control | 3 | 5.333 | 4.163 |

===== GLMM analysis on number of plants emerged in season 2016 =====

## Generalized linear mixed model analysis

| | |
|---|---|
| Method: | c.f. Schall (1991) Biometrika |
| Response variate: | plants |
| Distribution: | poisson |
| Link function: | logarithm |
| Random model: | Rep |
| Fixed model: | Constant + Treatment |

Dispersion parameter fixed at value 1.000

## Estimated variance components

| Random term | component | s.e. |
|---|---|---|
| Rep | 0.382 | 0.404 |

## Residual variance model

| Term | Model(order) | Parameter | Estimate | s.e. |
|---|---|---|---|---|
| Dispersn | Identity | Sigma2 | 1.000 | fixed |

## Tests for fixed effects

Sequentially adding terms to fixed model

| Fixed term | Wald statistic | n.d.f. | F statistic | d.d.f. | F pr |
|---|---|---|---|---|---|
| Treatment | 63.56 | 6 | 10.59 | 12.0 | <0.001 |

## Back-transformed Means (on the original scale)

| Treatment | | |
|---|---|---|
| B | 12.016 | a |
| BC | 14.068 | a |
| BP | 1.758 | c |
| BPC | 4.396 | bc |
| C | 2.052 | bc |
| CC | 5.275 | b |
| Control | 4.103 | bc |

========== Summary of mean counts and SDs ==========

| | Nobservd | Mean | s.d. |
|---|---|---|---|
| Treatment | | | |
| B | 3 | 13.667 | 15.011 |
| BC | 3 | 16.000 | 13.454 |
| BP | 3 | 2.000 | 1.000 |
| BPC | 3 | 5.000 | 2.646 |
| C | 3 | 2.333 | 1.155 |
| CC | 3 | 6.000 | 4.583 |
| Control | 3 | 4.667 | 4.041 |

===== GLMM combined analysis on number of plants emerged in both seasons =====

## Generalized linear mixed model analysis

| | |
|---|---|
| Method: | c.f. Schall (1991) Biometrika |
| Response variate: | plants |
| Distribution: | poisson |
| Link function: | logarithm |
| Random model: | Season + Season.Rep |
| Fixed model: | Constant + Season + Treatment + Season.Treatment |

Dispersion parameter fixed at value 1.000

## Estimated variance components

| Random term | component | s.e. |
|---|---|---|
| Season.Rep | 0.370 | 0.276 |

## Residual variance model

| Term | Model(order) | Parameter | Estimate | s.e. |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Dispersn | Identity | Sigma2 | 1.000 | fixed |

## Tests for fixed effects

Sequentially adding terms to fixed model

| Fixed term | Wald statistic | n.d.f. | F statistic | d.d.f. | F pr |
|---|---|---|---|---|---|
| Season | 0.00 | 1 | 0.00 | 4.1 | 0.976 |
| Treatment | 109.90 | 6 | 18.32 | 26.0 | <0.001 |
| Season.Treatment | 3.65 | 6 | 0.61 | 26.0 | 0.721 |

## Back-transformed Means (on the original scale)

| Season | | |
|---|---|---|
| 2015 | 5.935 | a |
| 2016 | 4.794 | a |

| Treatment | | |
|---|---|---|
| B | 11.621 | a |
| BC | 14.424 | a |
| BP | 2.793 | cd |
| BPC | 4.561 | bc |
| C | 2.337 | d |
| CC | 5.586 | b |
| Control | 4.407 | bcd |

| Treatment | B | BC | BP | BPC | C | CC | Control |
|---|---|---|---|---|---|---|---|
| Season | | | | | | | |
| 2015 | 11.235 | 14.783 | 4.435 | 4.731 | 2.661 | 5.913 | 4.731 |
| 2016 | 12.021 | 14.073 | 1.759 | 4.398 | 2.052 | 5.278 | 4.105 |